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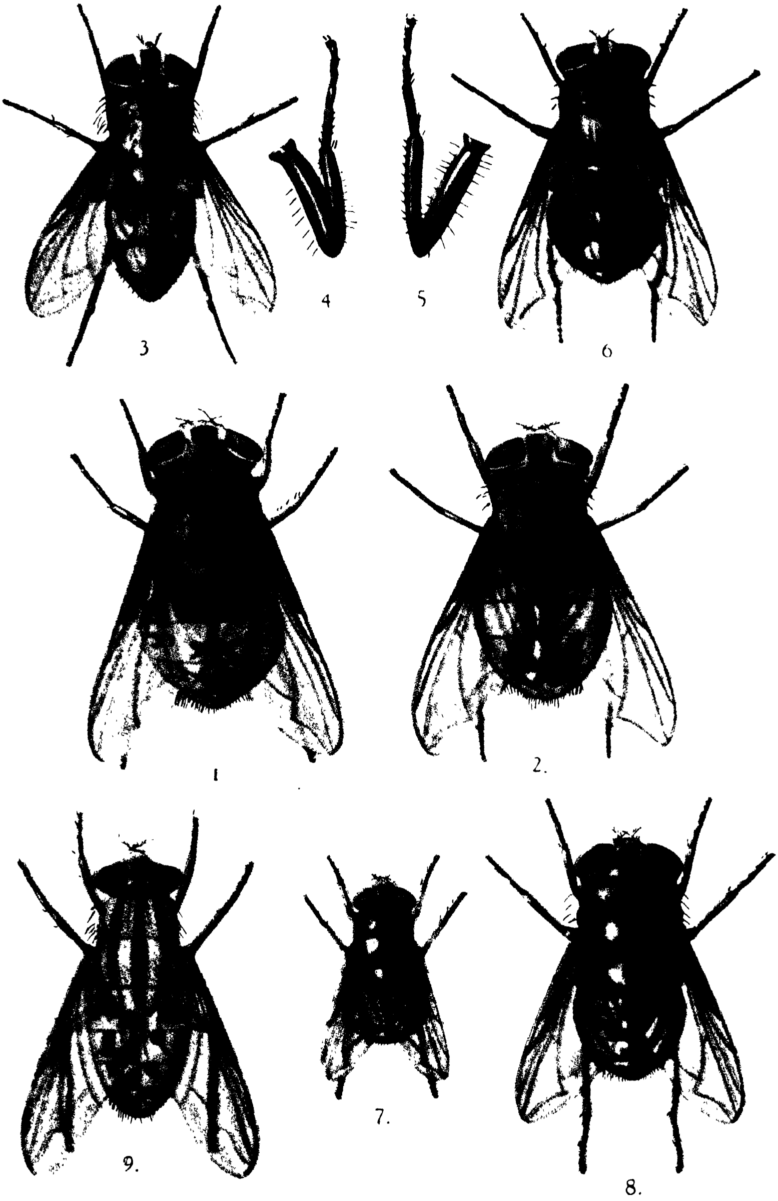
INSECTS AFFECTING LIVESTOCK



The blowflies concerned in strike in sheep in Australia. 1. Large brown blowfly (*Calliphora stygia*). 2. Lesser brown blowfly (*C. augur*). 3. Primary green blowfly (*Lucilia cuprina*). 4. Foreleg of *L. cuprina*, showing green femur. 5. Foreleg of European green blowfly, *L. sericata*, showing black femur. 6. Secondary green blowfly or hairy maggot fly (*Chyrsomyia rufifacies*). 7. Small green blowfly (*Microcalliphora varipes*).8. Steel-blue blowfly (*C. micropogon*). 9. Flesh fly (*Sarcophaga froggatti*).

(*From Pamphlet No.* 37, *C.S.I.R.O.*)

Australian Agricultural and Livestock Series

INSECTS
AFFECTING LIVESTOCK

With Special Reference to Important Species
Occurring in Australia

BY

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PREFACE

THERE is already a number of text-books on veterinary entomology, but in many of these attention is directed mainly to the morphology of the various important insects, mites, and ticks, and little information is given regarding their life histories, economic importance, and control. Moreover, most writers have dealt with species of both medical and veterinary interest, and have stressed the medical aspects to such an extent that insects of purely veterinary interest are given relatively scant mention. Also, there has been a tendency—which is of course quite understandable—on the part of the various authors to devote most attention to the pests occurring in their own countries and to give relatively little information about those prevalent elsewhere. There is, therefore, a need for a reference book dealing primarily with the important species in Australia, giving particular attention to their life histories, their economic importance, and the methods of treatment and control applicable to Australian conditions and methods of husbandry.

An attempt has been made to present the material in a way that will be useful to both the scientific worker and the farmer or grazier. As might be expected, this has proved a difficult task, but by keeping the technical sections—in which classifications, definitions, and keys to identification are set down—separate from the simpler descriptions of life cycles, economic importance, and control, I hope for some degree of success.

Descriptions of the various insects, mites and ticks mentioned are fairly brief, and reliance for their identification has been placed on a few outstanding characters, which for the most part are set out in the form of keys.

There are a number of people without whose assistance this book could not have been prepared. Mr A. F. Bell, Under Secretary, Queensland Department of Agriculture and Stock, kindly permitted the use of a large number of illustrations prepared by the late I. W. Helmsing, many of which are published for the first time. Mr G. Moule, Director, Sheep and Wool Branch, Queensland Department of Agriculture, and Mr H. D. Carter, Wool Biology Laboratory, C.S.I.R.O., lent several photographs. Mr R. K. Keith, Veterinary Parasitology Laboratory, C.S.I.R.O., Yeerongpilly contributed many photographs which are published for the first time. Mr L. F. Hitchcock, Division of Entomology, C.S.I.R.O., was gracious enough to allow the use of data on the bionomics of the cattle tick, *Boophilus microplus*, which have previously appeared only in annual reports. The manuscript was read by, and valuable criticism of it was received from, Mr D. A. Gill, Assistant Chief, Division of Animal Health and Production, C.S.I.R.O., Dr I. M. Mackerras, Director, Queensland Institute of Medical Research, and Mr P. J. O'Sullivan, Parasitologist, Animal Health Station, Yeerongpilly. To all these colleagues I wish to record my gratitude for their assistance.

I also have to thank the many authors who permitted me to use their illustrations. Some of these authors, unfortunately, I was unable to thank personally. Finally I must express my gratitude to the publishers, Angus and Robertson Ltd, Sydney, at whose suggestion the preparation of this book was undertaken.

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SECTION I

GENERAL

OVER 800,000 different species of insects*, mites, and ticks have been recorded from various parts of the world, more than half of which are dependent on plants or animals for food. Because of their tremendous numbers, their capacity for rapid multiplication, and their need of foods required by man, insects are man's greatest rival for the world's available food-supply, a competition of the greatest importance today because of the serious food shortage.

Authorities in the United States have estimated that insects destroy fully one-tenth of that country's agricultural production, an annual loss of more than one billion dollars, of which 168 million dollars can be debited to insects associated with livestock. The few estimates of losses among livestock available from other countries indicate that these also suffer severely. Sheep blowflies, for example, were computed some years ago to cost Great Britain £860,000 a year, and, in Australia annual losses from this source have been given as no less than £4,000,000. Warble flies are another cause of heavy loss, and the depreciation in cattle hides alone is considered to be worth at least 700,000 dollars in Canada and £750,000 in Great Britain yearly.

All sections of the livestock industry in Australia suffer severely from insect attack. The losses are undoubtedly greatest in the sheep industry, where the most important pests are blowflies, lice, and ked. Nasal bots and itch-mites also take their toll. In the cattle industry the common cattle tick is responsible for greater losses than any other disease. The buffalo fly is almost as important, and lice are common and widespread. Horses are attacked by bush-flies, bot-flies, and lice. In addition to the wastage caused by these major pests, consideration must be given to the myriads of mosquitoes, sandflies, black-flies, and fleas that can make life very miserable for livestock and can, at times, even cause death.

The more serious insect pests in Australia have been introduced from other countries, and include the primary green sheep blowfly, the common cattle tick, the poultry tick, the buffalo fly, the bot-flies, the lice, the sheep ked, and the important fleas. There are also a number of indigenous insects that are capable of inflicting severe injuries, such as the brown sheep blowflies, mosquitoes, sandflies, the bush-fly, the itch-mites, and the scrub tick. Although the losses among livestock in Australia are severe, the country is fortunate in the absence of such important pests as warble fly, screw-worms, and sheep-scab, while sarcoptic mange is seen only in the pig and dog. There is, furthermore, a remarkable scarcity of highly pathogenic insect-borne diseases, for even though a large proportion of her livestock is found in tropical and sub-tropical areas, Australia's insect-borne diseases of this type are restricted to the tick fevers of cattle and poultry.

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* Hereafter the term "insect" will be used to include the allied mites and ticks.

HOW INSECTS CAUSE LOSSES

The majority of insects that cause injuries to livestock are parasites during some stage or other of their life cycle. They live on the tissues or blood of the animal or bird host, and are in most cases entirely dependent on it for their existence. Most parasitic species live on the skin surface of their host, feeding on the scales and debris there, or on the blood and fluids that they obtain by piercing the skin. These are external parasites or ectoparasites, and include the lice, fleas, ticks, and biting flies. Others—for example, the larvae of the bot-flies and the poultry air-sac mite—live in tissues and organs inside the body of the host, and are known as internal parasites or endoparasites. Some parasites, such as lice and mange-mites, are so closely associated with their host that should they be removed they would die; whereas others, such as the biting flies, are interested in the host only when they are hungry.

In addition to those insects that are directly injurious because of their parasitic habits, there are a large number that may cause even greater losses, for they transmit the organisms of serious diseases, including protozoa, bacteria, viruses, rickettsiae, spirochaetes, and helminths. It is interesting to note that there is no disease of fungal origin definitely known to be transmitted by insects to livestock or man.

In the majority of insect-borne diseases the insect is essential not only for the transmission of the disease organism from one host to another, but also for its development, the organism undergoing certain changes in the insect's body before it can be transmitted. In such cases the insect is known as an intermediate host. Many intermediate hosts are parasitic and become infected with the causal organism during the act of sucking blood. After reaching the infective stage in the intermediate host, the organism is then transmitted during the act of biting and sucking blood. In this way ticks, mites, and blood-sucking flies transmit disease. The tick fevers of cattle and poultry, typhus and malaria of man, nagana of cattle, encephalomyelitis of horses, and heart-worm of dogs are diseases of this type.

Other insect intermediate hosts are free-living and become infected when they use the excretions of the host, usually the dung, for feeding or breeding purposes. When the organism has reached the infective stage in the insect it is transmitted to the final host, usually when the insect, in which it lies, is eaten. In this way various beetles, ants, and other free-living insects act as vectors of many worm diseases.

Some diseases are transmitted by insects accidentally, when the disease organism adheres to an insect's mouth-parts, body or legs and is carried from one animal to another. Sometimes an organism may be ingested by an insect and later excreted where it is available to a suitable host. This is known as mechanical transmission. The insect is called a mechanical vector and is not essential for the transmission of the disease. Tuberculosis, for example, may be spread by flies, but these insects are not the only factors in the transmission of this disease. Mechanical vectors are found among insects that feed on excretions and infections, and sometimes also on blood, and may play an important part in the epidemiology of certain diseases, such as surra.

Finally, there are a few insects that become important because they have a severe sting, as is the case with bees and wasps, or because they are toxic when eaten by livestock.

As a result of these associations, mortalities may occur, or the animals may suffer worry and irritation, loss of blood, or accidental injuries.

Mortalities. These may be serious where insect-borne diseases, or the ingestion of toxic insects, are concerned, but as a rule they are not spectacular where the injuries are a direct result of an insect's parasitic habits. There are exceptions of course, the most notable ones under Australian conditions being the serious mortalities among lambs that can be caused by black-flies, and among baby pigs by mosquitoes.

Worry and Irritation. All ectoparasites cause some degree of irritation to the host. Even biting lice, which feed on scales and other debris on the surface of the skin, can be responsible for serious annoyance simply through their movements over the skin. With parasites that pierce the skin, the pain of the bite is an additional irritation.

A few parasites may do little harm, but when they are numerous the worry and annoyance may drive livestock frantic in their efforts to obtain relief. Infected animals spend a considerable part of their time in biting, scratching, and restlessly moving about. Their feeding and resting periods are seriously curtailed, and the animals may fail to make normal weight-gains—they may even lose weight—and productivity in milk and eggs may be seriously retarded. Unless the infestation is given attention the animals may eventually reach a stage of exhaustion that proves fatal. Furthermore, when the vitality of an animal has thus been reduced by insect pests, the animal becomes susceptible to other diseases and also to inclement weather conditions. These ill-effects are usually insidious and not particularly easy to detect until they have become more or less pronounced.

Some parasitic insects cause more worry and annoyance than others. The most dangerous include the blowflies, whose larvae infest the flesh of living animals; in this case, not only is the worry and irritation caused by infestation extremely severe, but the living flesh is destroyed and harmful toxins from this destroyed tissue are absorbed into the body. Other dangerous species include the mange-mites, which cause serious inflammation and other injuries to the skin.

Loss of Blood. When blood-sucking insects infest an animal in great numbers they may deprive it of so much blood that it develops anaemia. This pathogenic condition is a conspicuous sequence to heavy tick infestations.

Blood-sucking insects inject a salivary fluid into the wound they make when feeding, and this frequently has unfavourable, and sometimes fatal, effects.

Accidental Injuries. Wounds, such as wire cuts and bruises, are a common occurrence among animals that have become terror-stricken through the attacks of bot-flies, warble flies, march-flies, and black-flies. Sometimes broken limbs and other severe and even fatal injuries are sustained by animals in their frantic attempts to avoid these pests.

In addition to the wastage from worry and irritation, loss of blood, etc., damage is often done to animal products, and considerable expenditure is required to control the pests. For example, warble flies are responsible for serious losses through the damage they cause to cattle hides, and also through the condemnation of infested parts of the carcass. Tick-bites also damage the hide—in 1915, when cattle hides were selling at a high price, the loss from this source in Queensland alone was given as £150,000. A high percentage of the losses to the sheep industry caused by insect pests can be attributed to the great damage done to wool by blowflies, lice, and keds. In the United States, where the production of mohair is an important industry, severe losses have been experienced because of screw-worms and lice.

The expenditure involved in control measures commences with the quarantine services, whose primary purpose is to prevent the introduction of new pests and diseases. The control of those pests already present is shared by the various Governments and by the farmer and grazier. To obtain an idea of the enormous cost the community is forced to bear consideration need not go beyond such major pests as cattle tick and sheep blowfly.

Within the cattle areas, plunge dips of 2000- to 3000-gallon capacity have been built at strategic points, so spaced that cattle have only short distances to walk for treatment. To the cost of constructing dips and the cost of the insecticides with which they are filled must be added that of mustering the cattle for treatment. In heavily infested areas and during the season of tick activity, some properties spend as much as 90 per cent of their time in mustering and dipping to control ticks. The infested States have also to maintain large staffs and many dips to prevent the ticks from spreading, and in New South Wales alone this costs in the vicinity of £450,000 per annum.

In the case of sheep blowfly, the cost of crutching, jetting, the modified Mules operation, and the frequent mustering and dressing of sheep during outbreaks must all be charged against blowflies.

DIAGNOSIS AND CONTROL

In diseases caused by insects *per se*, diagnosis is usually relatively simple, much more so than is the case with other pathogenic forms. The various species of insects are for the most part readily visible to the naked eye, and usually all that is required is a knowledge of the species and of the harm it can cause. Frequently a decision rests on the number of parasites present, but in some of these cases diagnosis is difficult and can be made only by an experienced person. The most important point in a diagnosis is the correct identification of the species concerned, so that the proper control measures may be applied.

The control measures in use against insects affecting livestock are concerned with (*a*) a reduction in the numbers of the insect so that it is no longer of any economic significance; (*b*) protection of the animal from attack; and (*c*) legislative procedures to prevent the introduction and/or spread of dangerous species. The habits and life history of any insect must be thoroughly understood before control can be efficiently undertaken.

MEASURES TO REDUCE THE INSECT POPULATION

The ideal objective is, of course, complete eradication. In the case of insects affecting livestock this has been attempted with the cattle ticks, *Boophilus annulatus* in the United States and *B. microplus* in New South Wales, and with the sheep-scab mite, *Psoroptes ovis*, in Australia. *B. annulatus* is now practically unknown in the United States; sheep-scab has not been seen in Australia since the close of the nineteenth century; while in New South Wales large areas have been freed from the depredations of *B. microplus*. Eradication of any pest or disease is an extremely costly procedure, but it now seems that with the high efficiency of the newer insecticides, eradication of many of the more important pests will be more feasible than it was in the past. In the meantime, effective control of all these parasites is possible through the application of one or more of the following measures.

General Sanitation. This simply means clean conditions in and around stables, dairies, pigsties, and poultry-houses. Heaps of old rubbish and vegetation attract and provide shelter for many disease-carrying insects. Stable flies breed in rotting vegetation and mosquitoes in water contained in old tins and other receptacles.

The frequent collection and effective disposal of manure eliminates the source of infection of many diseases and prevents house-flies from breeding therein.

Animal accommodation should be so constructed that it can be kept clean. Good drainage is most important. Parasites such as lice and mange-mites may be spread by curry-combs, harness, rugs, etc. Cleanliness here is also necessary.

Elimination of Swampy Areas and Depressions. This is necessary for mosquito and sandfly control.

Reservoir Hosts. Some species of parasites may at some stage of their life cycle infest hosts other than domestic animals and birds, on which the populations can be maintained and even increased. The scrub tick, *Ixodes holocyclus*, is spread by various marsupials, the cattle tick, *Boophilus microplus* by horses, sheep, and deer, and the poultry stickfast flea, *Echidnophaga gallinacea*, by a number of animals and birds, both domestic and wild. These reservoir hosts must be considered when planning control measures for these particular parasites.

Animal Husbandry. Efficient animal-management methods assist materially in minimizing the ill-effects of infestation and in maintaining the parasite populations on a low grade.

Pasture Management. With parasites that spend some period of their life cycle in the pastures, the exclusion of all known hosts will ultimately cleanse the pasture. The larvae of ticks may be eradicated in this manner.

Trapping. This method of control depends on the use of baits or lures to entice the insects into a container from which they cannot escape. Trapping is used for house-fly and tsetse fly control, and at one time was considered for blowfly control. Another form of trapping is seen when an insecticide with pronounced residual toxicity is applied to an animal, which thus becomes a moving poison-bait. For example, any larval ticks that attempt to attach themselves to cattle within fourteen days or so of the cattle's being sprayed with DDT will die.

Biological Control. This method employs parasites, predators, or diseases to control insects. It has never been exploited to any extent to control livestock parasites, except in the case of ticks, and here without any success. Several insect pests of plants, however, have been controlled in this manner.

Insecticides

The application of chemicals is the most widely used method of controlling insects. Such chemicals are known as insecticides and sometimes, where mites and ticks are concerned, as miticides and tickicides. Those that kill after being ingested by the insect are known as stomach poisons, and these are applied by mixing them with the insect's food. Others kill after application to the insect's body, and are known as contact poisons. They are generally absorbed through the cuticle, especially through the softer places in the exoskeleton, such as the pulvilli. The efficiency of a contact poison thus depends mainly on its ability to penetrate or permeate the insect cuticle. This is covered with a waxy layer and contains small canals filled with lipoid materials. Penetration is obtained chiefly by using chemicals that dissolve lipoids. The actual insecticide may be incorporated in a lipoid solvent. The classification of insecticides into stomach and contact poisons was easily made until the advent of some types of insecticide that could kill in either way. For the present purpose it is proposed to class the insecticides in use on livestock as of inorganic, organic, or plant origin.

Inorganic Compounds

Included amongst the inorganic compounds are arsenic, fluorides and fluosilicates, sulphur and boron compounds.

Arsenic. This chemical has been in use for over fifty years against ticks infesting cattle, horses, and sheep. Indeed, until the advent of the newer toxicants such as DDT it was the most widely used insecticide against these parasites. It is also employed against lice of cattle, horses, and sheep, being particularly effective against biting lice. Arsenic is not ovicidal against these insects, nor has it any effective residual toxicity, except in the case of the sheep-biting louse. The preparation generally used is a solution of arsenious acid in sodium hydroxide. The resulting compound is loosely known as sodium arsenite, but its chemistry is obscure. Arsenic is very toxic to the host and must be used with the greatest care.

Calcium arsenite and sodium arsenite are used as jetting fluids to protect against crutch strike in sheep.

Arsenic and its compounds are stomach poisons, though, in the case of ticks, arsenic appears to act mainly as a contact poison.

Fluorides and Fluosilicates. Sodium fluoride and sodium fluosilicate are effective against lice, especially biting lice, and have their greatest application against poultry lice. They are also employed to control cockroaches. These are stomach poisons.

Sulphur. This element and its compounds are well-known insecticides for mites, in the form of an ointment, as lime sulphur, or as potassa sulphurata. In the United States, wettable sulphur of very fine particle size has been recommended against lice and warble fly larvae. In these cases sulphur is a contact poison. It can also be used as a fumigant (SO_2) against mange-mites.

Boron. Boric acid and its compounds, the borates, are incorporated as stomach poisons in blowfly dressings in Australia. When applied to manure heaps borax will control breeding by the house-fly.

Organic Compounds

With the exception of mineral oils and tar distillates, organic insecticides are of comparatively recent origin.

Oils have been used as insecticides over a long period. Kerosene and crude oil are the best known and are employed for the control of such insects as lice, fleas, and ticks. They kill by smothering the insect. Coal tar products such as phenols and cresols are contact insecticides that are used mainly against lice. They are effective poisons but are comparatively toxic to the host. The newer insecticides include the chlorinated hydrocarbons, the most important of which are DDT, methoxychlor, benzene hexachloride (BHC), chlordane, toxaphene, the organic phosphates, lethane, thanite, benzyl benzoate, tetmosol, the phthalates, and orthodichlorobenzene.

Chlorinated Hydrocarbons. These may be regarded as highly effective insecticides, being lethal to the majority of insects in extremely small concentrations, and possessing a remarkable residual toxicity extending over many weeks, and in some cases months. They are all both stomach and contact poisons, and BHC is also a fumigant. A serious disadvantage of this group of insecticides is the resistance to them that may be developed by insects.

DDT and Methoxvchlor. DDT is an abbreviation for the compound dichloro-diphenyl-trichloroethane, or more specifically 2, 2 bis-(parachlorophenyl) -1, 1, 1-trichloroethane. It was first synthesized in 1874, but its insecticidal value was not apparent until 1939, when the firm of I. R. Geigy, Switzerland, reported its use against clothes moths, flies, and other insects.

The technical product consists of about 70 per cent of the para para isomer, the bulk of the remainder being the ortho para isomer, which has few insecticidal properties. DDT is a white crystalline substance, practically insoluble in water, but soluble in organic solvents. It has a remarkable toxicity against most insects and is used in very low concentrations. Its residual action is very pronounced, and it will continue to remain lethal to insects over prolonged periods. Its action is slow, and for this reason commercial DDT fly-sprays contain pyrethrum or some similar insecticide to ensure a quick knock-down. It is not ovicidal, and generally speaking its action against muscid and blowfly larvae, ticks, and mites is not of the same high order as against other insects.

Considerable work has been done on the toxicity of DDT to warm-blooded animals. Oily solutions on the skin are a particular hazard. DDT is stored in animal fat, and elimination is very slow. It appears in appreciable quantities in the milk of treated cattle, and in the United States it has been strongly recommended that the methoxy analogue, methoxychlor, should replace DDT in barns and on cows in production, for otherwise their milk is considered to constitute a risk of chronic DDT poisoning in man. DDT is highly toxic to cats.

DDT is highly effective against the majority of flies, the lice, fleas, and ticks. It will also control the larvae of mosquitoes, sandflies, and black-flies. In some areas, strains of house-flies and mosquitoes have developed that have shown a marked resistance to this insecticide. These, however, are usually readily controlled with one of the other allied insecticides.

Methoxychlor is very similar to DDT, in its chemical, physical, and insecticidal properties, though its residual toxicity to insects is not quite so lasting. It is the least toxic of the chlorinated hydrocarbon insecticides to warm-blooded animals. Furthermore, since it is not stored in animal fat as DDT is, it can be used in comparative safety for fly control in barns and on animals.

BHC. This abbreviation or the trade name "Gammexane" is given to the compound benzene hexachloride, or 1, 2, 3, 4, 5, 6-hexa-chlorocyclohexane. The empirical formula is $C_6H_6Cl_6$, from which the name "666" is derived. This insecticide has been known since 1825, but its insecticidal properties have only recently been recognized. There are five known isomers, of which the gamma isomer is by far the most active. The commercial product is a solid with a pronounced musty, unpleasant odour, containing 11 to 14 per cent of the gamma isomer. It is soluble in organic solvents but not in water.

BHC is about ten times as toxic as DDT to most insects, but owing to its volatility it has less residual effect. It kills more rapidly than DDT and, in general, is more effective against ticks, mites, and larvae of the higher Diptera. Its musty odour prevents its use in household fly-sprays, for it may cause meat and egg taint. The pure gamma isomer is, however, odourless. Such a product is most closely represented by Lindane, which yields 95 to 98 per cent of the gamma isomer.

BHC is also highly effective against adult flies, lice, and fleas. The pure gamma isomer is less toxic than the other isomers, and shows less tendency to become stored in animal fat. It is also more quickly eliminated than the others. The use of BHC on livestock is fairly safe, but care should be taken not to exceed the recommended dosages. The development of strains of insects and of ticks that become resistant to this insecticide has been reported.

Chlordane. This compound is known as Velsicol 1068, or Octoklor. It is a colourless, odourless liquid readily soluble in most organic solvents. Lethal effects against insects are obtained with a dosage either lower than or close to that of DDT, whilst its residual effects appear to be better than those of BHC, but probably not as good as those of DDT. Its action is slow like that of DDT. In the limited tests that have been given to chlordane, it appears superior to DDT against ticks and mites. Orally it is only half as toxic as DDT, but its toxicity through the skin is very much greater. It is regarded as one of the most toxic chlorinated hydrocarbons to warm-blooded animals.

Toxaphene. Toxaphene ($C_{10}H_{10}Cl_8$) is a waxy substance with a mild piny odour, soluble in most organic solvents. Its action is slow, and the minimum lethal dose against many insects is lower than or close to that of DDT, but its residual effect is not as great.

Toxaphene is about four times as toxic as DDT when taken orally, and its toxicity when applied to the skin is also much greater. It has proved highly effective against ticks, but present formulations have proved toxic to calves.

Other Chlorinated Hydrocarbons. These compounds include TDE (Rothane 3) or tetrachlorodiphenyl ethane, dimethoxydiphenyl, trichloroethane, heptachlor, aldrin (Octaline or Compound 497) and dieldrin (Octalox). Preliminary work indicates that some of these may find a place in livestock pest control.

Organic Phosphates. Hexaethyl tetraphosphate (HETP), tetraethyl pyrophosphate (TEPP) and diethyl nitrophenyl thiophosphate (Thiophos, Parathion, E605) are included here. E605 is the best known and has given promising results against ticks. This is a heavy liquid, relatively insoluble in water, with an unpleasant onion-like odour. Considerable work remains to be done on these compounds because of their instability in the presence of water, and also because of their reported high toxicity to warm-blooded animals.

Other Compounds. Lethane 384, lethane 60, and thanite are thiocyanate compounds used as space sprays with pyrethrum, piperonyl butoxide or DDT against flies and mosquitoes. They have no advantage over pyrethrum. Tetmosol (tetraethyl-thiuram monosulphide) benzyl benzoate, dibutylphthalate, and di-methylphthalate are miticides, whilst orthodichlorobenzene is an excellent larvicide against house-flies.

Compounds of Plant Origin

Included among the compounds of plant origin are pyrethrum, rotenone (derris), and nicotine.

Pyrethrum. This is one of the oldest known contact insecticides and is prepared from the ground flower-heads of certain plants of the genus *Chrysanthemum*, *C. cinerariaefolium* being the most valuable. The active principle is an oily liquid containing pyrethrins and cinerins. Pyrethrum sprays are among the best known and most efficient sprays for the control of flies and mosquitoes. The pyrethrins and cinerins are extracted with highly refined petroleum oils such as kerosene. The concentrate is diluted with kerosene to contain 0·1 per cent pyrethrins, perfumes being added to improve the odour. Some manufacturers prepare the concentrated extract with solvents such as ethylene dichloride.

Modern pyrethrum sprays may contain DDT and also certain substances known as synergists, which, when added to an insecticide, increase the initial killing effects and are sometimes responsible for longer residual toxicity. Sesame oil, piperonyl cyclenene, and piperonyl butoxide act in this manner.

Used as a dust or aqueous suspension, pyrethrum is an efficient insecticide for lice and fleas.

There are some synthetic compounds closely related to pyrethrin of which allethrin is the best known. This compound is more toxic to some insects than pyrethrum, but not as toxic to others.

Rotenone. This active principle of derris-bearing plants is a well-known contact insecticide. The plants occur in many parts of the world and are used by the natives as fish poisons. *Derris elliptica* and *D. mallaccensis* are the only cultivated species and their roots yield 5 to 10 per cent rotenone. Rotenone is also present in plants of the genus *Lonchocarpus*. The Peruvian name for this and other rotenone-bearing plants is *cubé* (*L. nicou*) whilst in Brazil and Ecuador these plants are known as *timbo*.

The rotenone is extracted with organic solvents, or the derris roots, timbo, or cubé may simply be finely ground and used as a dust or aqueous suspension. Rotenone is highly effective against lice, fleas, the sheep ked, and ticks, and has some residual toxicity. It is slower acting than pyrethrum and has little toxicity to man and animals since the amounts used do not leave sufficient residue.

Nicotine. This is an alkaloid prepared by steam distillation of the tobacco plants, *Nicotiana tabacum* and *N. rustica*. It readily forms salts with acids and is usually marketed as nicotine sulphate, which contains approximately 40 per cent nicotine. Nicotine sulphate is a powerful contact insecticide, but owing to its volatility is active for only comparatively short periods. It is unstable at low temperatures. It is most frequently employed against scab and chorioptic mange-mites, but is also used as a fumigant against lice in poultry, and is very effective against cattle lice. Nicotine is highly toxic to animals and must be used with the greatest care.

The Application of Insecticides

Dusts. These are composed of finely ground particles of an insecticide mixed with an inert carrier such as clay of certain kinds. Dusts are worked into the hair or feathers of the host by means of a hand-shaker. Power dusters, a recent innovation, are used in the treatment of large numbers of animals. Sodium fluoride, sodium fluosilicate, pyrethrum, rotenone, and the chlorinated hydrocarbons are employed in this manner, though—

at least in the case of the latter—effective concentrations for dust formulations are five to ten times those required for use as liquids. Dusts may also be applied as a larvicide for mosquitoes.

Solutions, Suspensions and Emulsions. Arsenic and nicotine sulphate are employed as aqueous solutions. Pyrethrum, thanite, and lethane as space sprays are used in solution with kerosene. Petroleum-oil solutions of the chlorinated hydrocarbon insecticides, particularly DDT, are applied to walls, etc., for residual toxicity effects. The greatest care must be taken when using petroleum-oil solutions on the skin of animals, owing to the risk of irritation. For example, DDT in kerosene is used to control buffalo fly on cattle, but must be applied only in small quantities, just enough to wet the hair. When both the skin and coat are to be treated, insecticides insoluble in water are employed as emulsions or suspensions. Suspensions are made by dispersing very fine particles of the insecticide in water, usually by absorbing it on very finely ground clays. In emulsions the insecticide is dissolved in a solvent and this is then dispersed as fine globules in water by means of emulsifying agents. The particle size of the dispersed phase is important, also the type and concentration of the wetting agent.

These liquid formulations may be applied as washes, sprays, jets, or aerosols.

Washes. Small animals or small numbers of large animals may be washed by hand. When large numbers of animals are concerned the insecticide is placed in a dipping tank or vat, into which the animals are plunged. Vats for dipping cattle may contain up to 3000 gallons of insecticide. Provision is made for retaining the excess fluid that will drain from the treated animals.

Sprays. These may be finely atomized, as when used against adult flies and mosquitoes. For such a purpose a spray gun of the household type is employed. When animals are to be wet quickly a coarser type of spray is necessary, and spray appliances of the knapsack or bucket pump types are used. The present tendency is to use a fine spray with pressures up to 400 pounds. Shower sprays have been developed for the treatment of sheep and cattle, and where large areas of country are to be covered—for example, for mosquito control—sprays are applied from aircraft.

Jets. This method of application is confined to the treatment of sheep as a preventive against blowfly strike. The insecticide is applied as thin jets under pressure, so that the wool is thoroughly saturated to the skin surface.

Aerosols. An aerosol is a fine dispersion of a liquid or solid in a gas, the droplets being so minute as to remain suspended for hours. The most effective range of particle size is 10 to 20μ. The Freon bomb is an example of a liquified gas aerosol for confined or restricted spaces. In bombs of this type the insecticide—pyrethrum, DDT, etc.—is dissolved in a non-volatile solvent and placed in a metal cylinder with a liquified gas such as Freon 12. On the opening of the valve the vapour pressure of the gas ejects the mixture into the air, where it boils, dispersing the insecticide in the form of an aerosol.

For outdoor use thermal-generated aerosols are employed. These may be formed by spraying solutions onto a hot surface to form a vapour that immediately on contact with the cooler air forms a fog, or by pumping an oil and water mixture of the insecticide through a heated coil. Superheated steam is formed, which forces the mixture through the nozzles and disperses it in very fine particles. The generator is mounted on a motor-truck and moved back and forth across the wind.

Aerosol application has been developed in the United States, and has been concerned mainly with DDT. Satisfactory results have been obtained against such pests as horn-flies, tsetse flies, mosquitoes, and sandflies.

Smokes. By taking advantage of the volatility of an insecticide on heating, insecticidal smokes may be manufactured by impregnating some basic material with the insecticide and with some chemical that smoulders on ignition, such as potassium nitrate. Very little work has been done on the insecticidal value of smokes, though DDT, BHC, and pyrethrum smokes are available.

Fumigation. This method of application is well illustrated in the use of nicotine sulphate and BHC for controlling poultry lice. These chemicals are painted on the perches, and volatilization is brought about by the heat of the bird's body. Sulphur fumigation has its uses against mites and lice in oversea countries, whilst hydrocyanic gas finds wide application against bed-bugs.

Feeding Insecticides to the Host. This method has a definite appeal to most livestock owners as a possible means of control, mainly because of the apparent ease of application. During recent years several drugs have proved to be effective when used in this way. Phenothiazine will prevent horn-flies from breeding in the dung of animals to which it has been administered. DDT, BHC, chlordane, and certain indandione compounds given to animals will kill insects attempting to feed on them, such as tsetse flies, mosquitoes, bed-bugs, keds, ticks, and lice. Unfortunately, in most cases the doses necessary for these effects have been found to be toxic to the host.

Spraying or Painting the Resting Places of Insects. The chlorinated hydrocarbon insecticides, because of their prolonged residual toxicity are capable of controlling insects such as flies and mosquitoes when applied to surfaces on which they rest. This effect, at least in the case of DDT, is maintained when the insecticide is incorporated in a paint.

MEASURES TO PROTECT THE HOST

Repellents. These are chemical substances that, by being offensive to the insect or by masking the attractive odour of the host, provide a temporary respite from attack. The repellents in early use were mainly evil-smelling oils, such as fish or whale oil and certain essential oils, and were not very effective. Modern repellents give a much greater degree of protection, but, even so, it is only for a very short period, and this fact, together with the high cost, limits their use on livestock. Dibutyl- and dimethyl-phthalate, 2-ethyl-1, 3-hexaridiol (Rutgers 6-12), n-butyl mesityl oxide, (Indalone), dimethyl carbate and methyl N, N,—diisopropyl-adipamate are very effective against small biting flies such as mosquitoes and sandflies. Citronella is widely used in Australia to protect the marking wounds of lambs against blowflies. N- butylacetanilide is highly repellent to ticks.

Smudge fires are another method of protecting the host. The smoke has a repellent effect and serves to protect stock against mosquitoes and black-flies.

Mechanical Devices. The measures recommended to protect horses against throat and nose bot-fly attack include mechanical devices. In some countries where march-flies and stable flies are very abundant, protection is afforded by clothing the animals in hessian or canvas.

Screening. Fly gauze screens on the windows and doors of stables will exclude such pests as mosquitoes and flies.

Farm Practices. The incidence of blowfly strike may be considerably decreased by such station practices as shearing, crutching, docking the tail and surgically removing the breech folds, and by the application of residual insecticides.

New stock should always be isolated for a period. This is an essential step in the control of all types of disease. Poultry, for example, should be isolated in case they are carrying the larvae of the poultry tick.

Breeding of Resistant or Non-Susceptible Animals. Some animals are more resistant to attack than others. Although little work has been done on this aspect of control, it should always be kept in mind. For example, cattle with Zebu blood are considered more resistant to ticks than pure English breeds. Breeding towards a plain-bodied sheep has been advocated for sheep blowfly control.

Legislation. The legislative control of parasites aims, firstly, at preventing the introduction of new pests into the country by quarantine and, secondly, at restricting the spread of those insects already established within the country. Warbles and sheep-scab, for example, are not present in Australia, and a close watch is maintained on imported cattle and sheep for these parasites. The distribution of pests already present in the country, particularly if they are spread only *per medium* of their host, is restricted by regulations concerned with the movements and treatment of the host. Cattle tick, for example, is prevented from spreading by regulations designed to ensure that all cattle moving from tick-infested to clean areas are free from ticks. Lice and ked on sheep, stickfast flea on poultry, and buffalo fly on cattle are also controlled in this manner.

In a few cases legislation has been formulated for the eradication of insect parasites. Success has been obtained with the cattle tick in the United States and in certain districts in New South Wales, and with sheep-scab in Australia generally.

THE NAMING OF INSECTS

Among human beings each individual is distinguished by name. Among all other living things, on the other hand, a name is applied only to certain groups of individuals, which are all alike morphologically and are capable of breeding together to give rise to fertile offspring. Such a group is known as a species and is the natural reproductive unit.

The system of naming is called the binomial system of nomenclature, and is applied according to certain regulations, to which scientific workers throughout the world have agreed. Each species has two names, written in Latin form; for example, *Argas persicus,* which is the scientific name of the poultry tick. The word *Argas* represents the genus and the word *persicus* the species. A genus is simply a collection of species linked together by certain common characters. Similarly a family or subfamily is a collection of genera, a superfamily a collection of families, and so on. The subfamily name is formed by adding **-inae** to the stem of the typical genus, the family by adding **-idae,** and the superfamily by adding **-oidea.** Allied superfamilies constitute an order, allied orders a class, and allied classes a phylum. This arrangement is termed a classification.

People who do not understand the binomial system of nomenclature are frequently irritated and confused when they find changes in the names of certain species. But these changes take place according to the rules of the system, the most important of which is known as the law of priority. By this law the correct specific name for an insect or any other living thing is the name under which it was first described. Several descriptions with different names by different people are not infrequent for a single species, and it is a matter of determining which description and name was published first. The other names then become synonyms of the first name. Changes may also occur in the generic name, when, for example, the species is found to belong to a genus other than that in which it was described. Sometimes also the genus is discovered to be synonymic with an earlier described genus. As an example, the biting louse of the dog was first described in 1778 by De Geer as *Ricinus canis.* Nitzsch in 1838 described the same species as *Trichodectes latus.* The specific name given by De Geer has priority because of the earlier date, whilst the generic name given by Nitzsch is the correct one. Hence the dog louse is now known as *Trichodectes canis.* Sometimes the generic or specific name is found to be occupied by an earlier described genus or species, and in this case the names become homonyms and must be replaced.

The scientific name for a species is written in italics. The name of the author responsible for the species follows, the three names being written without punctuation. The date of the description may follow, separated from the author's name by a comma. If the generic name has been changed, the author's name and date is enclosed in brackets and sometimes is followed by the name of the person responsible for the change of generic name and the date on which this change was made. Thus the dog louse is written: *Trichodectes canis* (De Geer, 1778) Nitzsch, 1838. Or more simply: *Trichodectes canis* (De Geer).

CLASSIFICATION

Throughout the book the term "insect" is used to include not only the true insects, but also the spiders, mites, and ticks. This is not scientifically correct, but conforms to the common use of the name in textbooks such as this.

Insects, spiders, mites, and ticks belong to the zoological phylum

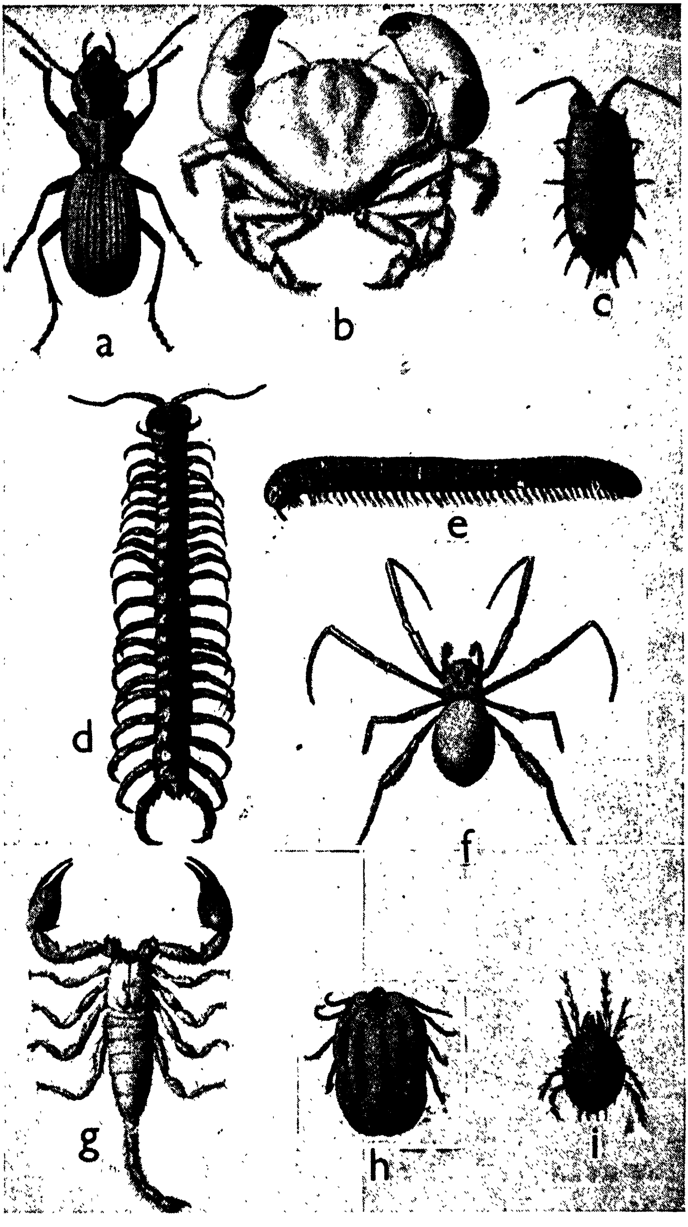

Fig. 1. Representatives of the Phylum Arthropoda. (*a*) An insect (Insecta); (*b*) a crab (Crustacea); (*c*) a wood louse (Crustacea); (*d*) a centipede (Myriapoda); (*e*) a millipede (Myriapoda); (*f*) a spider (Arachnida); (*g*) a scorpion (Arachnida); (*h*) a tick (Arachnida); (*i*) a mite (Arachnida). (All figures not to same magnification.)

(*After Helmsing.*)

Arthropoda, which also includes the centipedes, millipedes, crabs, crayfish, and shrimps. All these possess a hard chitinous exoskeleton, bilateral symmetry, a jointed body and appendages, a ventral nervous system, and a dorsal heart (Fig. 1(*a*)-(*i*)).

The system of classification of the Arthropoda adopted here is regarded by many zoologists as absolete. However, it suits the present purpose and divides the phylum into six classes, namely Onychophora, Crustacea, Myriopoda, Arachnida, Insecta, and Pentastomida.

Class ONYCHOPHORA

Terrestrial, externally unsegmented and worm-like; one pair of antennae and numerous paired, imperfectly segmented legs.

This class includes Peripatus, which is not of veterinary interest.

Class CRUSTACEA

Head and thorax frequently combined to form a cephalothorax; two pairs of antennae, numerous paired biramous appendages on the abdomen; essentially aquatic.

The crabs, crayfish, shrimps, water fleas, and wood-lice are included in this class (Fig. 1 (*b*), (*c*)). Certain species are intermediate hosts of worm parasites in man and animals.

Class MYRIOPODA

Terrestrial, with an elongate, segmented body provided with numerous pairs of jointed legs; one pair of antennae.

Here are included the centipedes with typically one pair of legs to each body segment, and the millipedes with two pairs (Fig. 1 (*d*), (*e*)). The former have a pair of poison claws with which they paralyse insects and other prey. Some of the larger species are capable of inflicting a very painful bite.

Class ARACHNIDA

Body divided at most into two regions, the head and thorax being fused together; four pairs of legs; no antennae.

This class contains the spiders, mites, and ticks (Fig. 1 (*f*) - (*i*)).

Class INSECTA

Body divided into three distinct regions; usually two pairs of wings, which may be reduced to one pair or may be absent; three pair of legs; one pair of antennae.

The true insects are included in this class (Fig. 1 (*a*)).

Class PENTASTOMIDA

Parasitic worm-like arthropods, which are considered to be related to the mites.

The only species of importance is *Linguatula serrata*, the so-called tongue-worm of the dog and other canines.

SECTION II

CLASS INSECTA

In all true insects the body is divided into three distinct regions, namely, the head, the thorax, and the abdomen. The head carries a pair of antennae and the organs of feeding. Attached to the thorax are three pairs of legs and usually two pairs of wings.

The skeleton, which is chiefly external, is a hard, chitinous covering with outgrowths such as spines, bristles, hairs, and scales. An internal skeleton is also present, its function being for muscle attachment and also to support the brain. The exoskeleton enables the dead and dried insect to maintain its shape and size.

External Morphology (Fig. 2)

The Head (Fig. 3). This is a globular or ovoid hardened capsule at the anterior end of the body. At the point of attachment is a rounded cavity, the posterior foramen, through which the oesophagus, dorsal aorta, central nervous system, and a pair of tracheae pass to the head. The head is composed of a number of plates or sclerites, including the gular plate, which bounds the foramen below and carries the lower lip or labium; the occiput, which closes the foramen above and is followed by the vertex, frons or forehead, and the clypeus, which bears the upper lip or labrum. On each side and below the eyes are the genae or cheeks.

Eyes are usually present and are situated one on each side above the genae. With few exceptions they are of the compound type, each consisting of a large number of hexagonal corneal lenses, each lens covering a single eye. In some insects, especially in the males, the eyes tend to meet one another along the mid-line, when they are said to be holoptic; if they are wide apart, as in many females, they are said to be dichoptic. In addition to these compound eyes, simple eyes or ocelli may also be present. These are usually three in number and are arranged in a small triangle on the vertex.

Situated between or in front of the compound eyes are the antennae. These are of diverse forms, but are usually elongate, segmented, and provided with a number of hairs. They are principally tactile in function and are apparently sensitive to air currents.

The Mouth-parts (Fig. 3). These consist of the labrum or upper lip, which closes the mouth above, the labium or lower lip, which closes it below, and two pairs of biting jaws, namely, the upper mandibles and the lower maxillae.

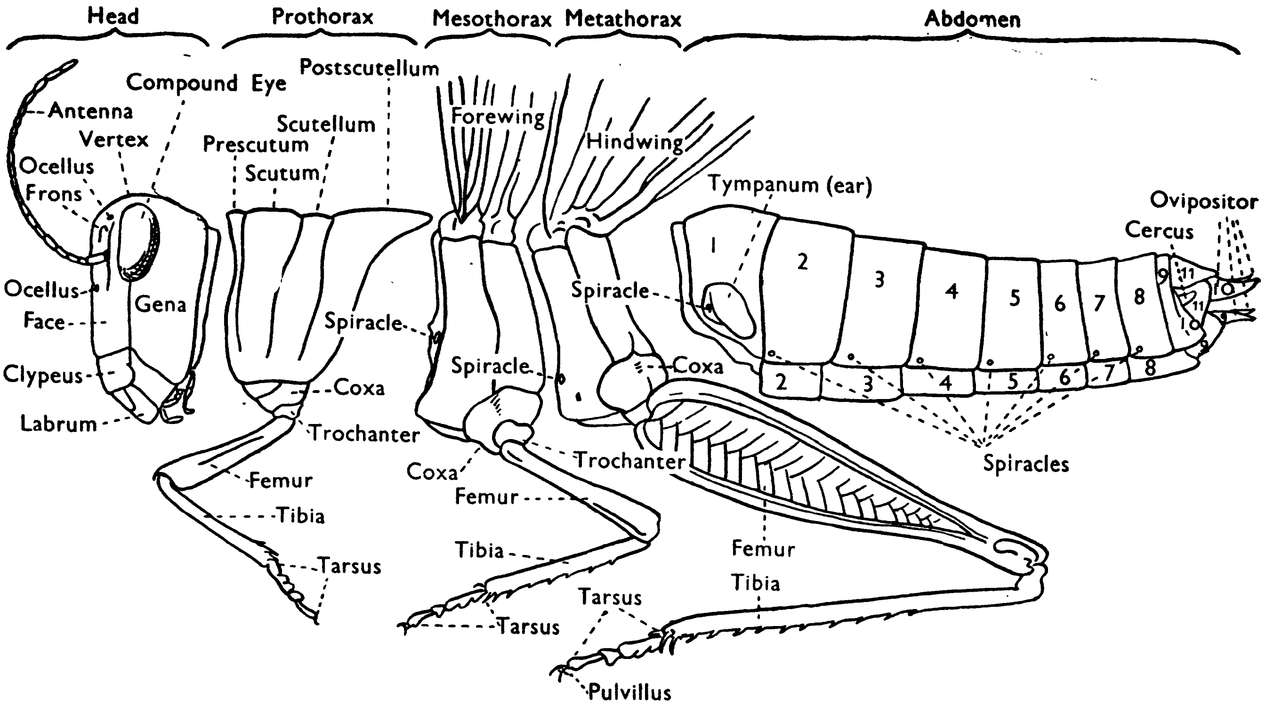

Fig. 2. The external morphology of an insect (a grasshopper).

(*After Herms.*)

The labrum is movable and is attached to the clypeus above it. On its inner surface are a number of tactile hairs and minute organs of taste, which constitute the epipharynx. The mandibles are situated one on each side below the labrum, are strongly chitinized, and provided with jaws. Below these and next to the labium are the maxillae, really the first maxillae. Each of these consists of a basal cardo, followed by a

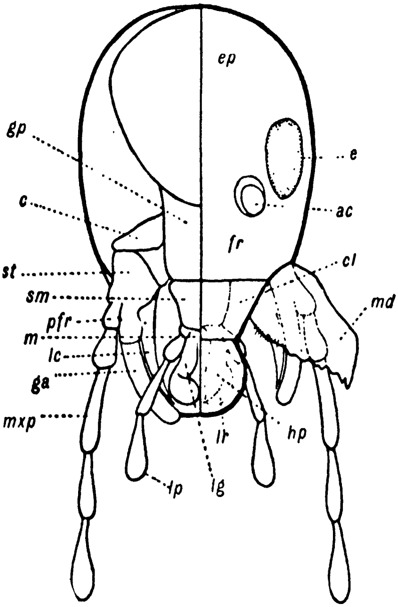

Fig. 3. The head of a chewing insect, showing head structures; right half, dorsal view; left half, ventral view; *ac.*, antennal cavity; *c.*, cardo; *cl.*, clypeus; *e.*, compound eye; *ep.*, epicranium; *fr.*, frons; *ga.*, galea; *gp.*, gular plate; *hp.*, hypopharynx; *lc.*, lacinia; *lg.*, ligula; *lp.*, labial palp; *lr.*, labrum; *m.*, mentum; *md.*, mandible; *mxp.*, maxillary palp; *pfr.*, palpifer; *sm.*, submentum; *st.*, stipes.

(*After Tillyard and Tonnoir.*)

stipes, from which there arises an inner lacinia and an outer galea. Arising from the outer distal portion of the stipes is a segmented palp, the maxillary palp. The maxillae select food by taste or touch, but are also at times provided with teeth for biting. The labium, which is composed of the fused second maxillae, has a basal submentum, followed by a mentum that may bear a pair of labial palpi. On the inner border of the mentum are two pairs of processes, the inner glossae and the outer paraglossae. These processes may sometimes be carried on a separate plate, the ligula.

Within the cavity of the mouth is the hypopharynx or tongue, which forms the lower border of the pharynx, extending as far back as the oesophagus. The salivary glands open on the hypopharynx.

This structure of the mouth-parts is seen in those insects where the jaws are used for biting and chewing. In insects where the mouth-parts are employed for sucking or piercing, however, modification and specialization in various directions has taken place.

The Thorax (Fig. 2). This is composed of three segments, the prothorax, mesothorax, and metathorax, each of which consists of a dorsal tergum, a ventral sternum, and lateral pleura; these are usually subdivided. In the mesothorax and metathorax the tergum may be divided into a large anterior scutum and a small posterior scutellum; and each pleuron into an anterior episternum and a posterior epimeron. The prothorax, mesothorax, and metathorax each bears a pair of legs that articulate with it ventro-laterally. The two pairs of wings are attached to the mesothorax and metathorax.

The Legs (Fig. 2). Each leg consists normally of a basal coxa, followed by a small trochanter, an elongate femur and tibia, and a tarsus, which is composed of a number of joints, usually five. The last tarsal segment is, in most cases, provided with a pair of claws, between which an empodium —a soft pad, spine, or bristle—may be present. A pair of narrow pads, the pulvilli, can be seen below the claws (Fig. 4).

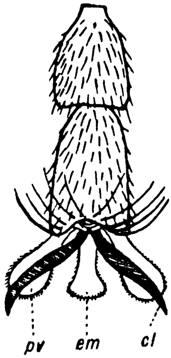

Fig. 4. Pulvillus and empodium; *cl.*, claw; *em.*, empodium; *pv.*, pulvillus.

(*After Tillyard and Tonnoir.*)

The Wings. Normally there are two pairs of wings, the forewings and the hindwings. These when developing are sac-like, but the upper and lower surfaces become applied to one another and in the adult appear as a simple membrane. Each wing has a costal border anteriorly, which curves towards the apex, while posteriorly the margin is also curved and may be divided into an anal lobe, an alula, an antisquama, and a squama. The wing is strengthened by veins or nervures, which are really tracheae and arise from two tracheal trunks at the base. The wing membrane frequently carries hairs or scales, either along the veins, over the whole surface, or as a marginal fringe. The veins follow the length of the wing, but there are also a number of cross-veins that divide the wing into cells. The longitudinal veins are plicated after the manner of a partially opened fan. The veins on the ridges are termed convex veins and those in the furrows, concave veins. The arrangement of the veins is termed venation, and it differs throughout the various orders. It is of great value in entomological systematics. There are several systems of naming the veins, all of which are founded upon various hypothetical origins of the veins. The system known as the modified Comstock-Needham system of nomenclature is usually adopted and is used here (Fig. 5 (*a*)).

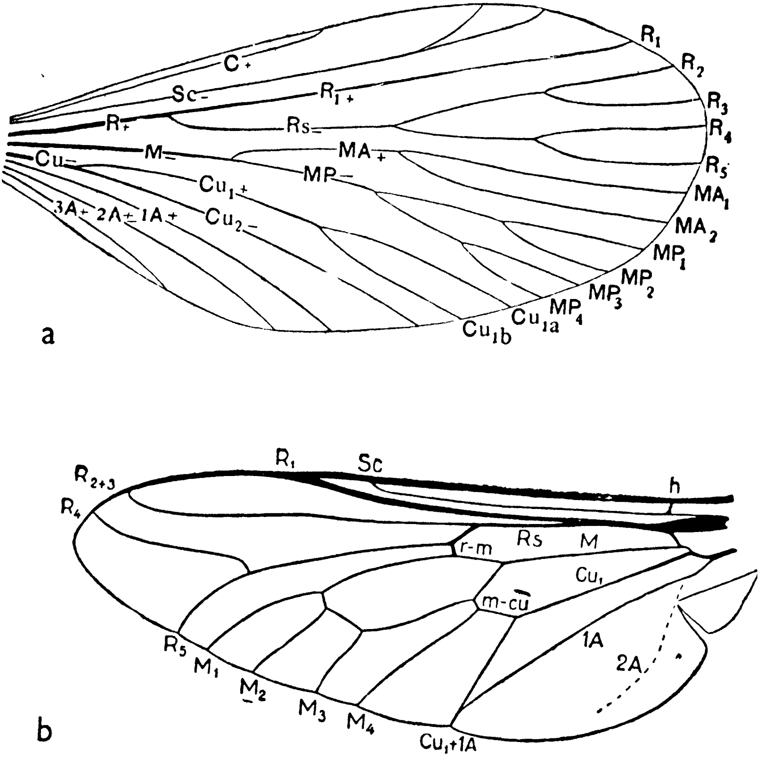

Fig. 5. (*a*) Hypothetical primitive type of wing venation (for reference to lettering, see text below). Convex veins+, concave veins —; (*b*) wing of tabanid, showing reduction in venation.

(*After Imms.*)

There are six longitudinal veins, named, in the order of their occurrence from the anterior border in the wing, the costa, the subcosta, the radius, the media, the cubitus, and the anal veins.

The Costa (*C*). This vein is unbranched and forms the anterior border of the wing.

The Subcosta (*Sc*). This vein is rarely branched.

The Radius (*R*). This divides into two branches, R_1 and R_s, the latter vein again dividing into four branches, R_2, R_3, R_4, and R_5.

The Media (*M*). This vein divides into an anterior vein MA, which subdivides into two branches, MA_1 and MA_2, and a posterior vein MP, with its four-branches MP_1, MP_2, MP_3, and MP_4. MA is usually missing and MP with its branches is known as M, M_1, M_2, etc.

The Cubitus (*Cu*). This has two branches, Cu_1 and Cu_2, Cu_1 subdividing into Cu_{1a} and Cu_{1b}.

Anal Veins. There are three of these, 1A, 2A, and 3A.

In the wing there are also a number of cross-veins that divide it into cells. The principal cross-veins are the humeral, the radial, the sectorial, the radio-medial, the medial, and the cubital.

The Humeral Cross-vein (*h*). This joins Sc and C near the humeral angle of the wing.

The Radial Cross-vein (*r*). This extends between R_1 and R_2.

The Sectorial Cross-vein (*s*). This is placed between R_3 and R_4 or R_{2+3} or R_{4+5}.

The Radio-medial Cross-vein (*r-m*). This runs between R_s and M, usually near the middle of the wing.

The Medial Cross-vein. This extends from M_2 to M_3.

The Cubital Cross-vein (*m-cu*). This runs between M and Cu.

The cells are designated according to the vein that forms the anterior border, for example, cell R_1, M_1, etc. If two veins have fused, as they frequently do, particularly in the higher orders, the vein is called, for example, R_{2+3}, M_{3+4} and the cell R_3 and M_4 respectively, since cells R_2 and M_3 have disappeared (Fig. 5 (*b*)). Sometimes a cell is divided into two or more sections by cross-veins, when the sections are designated according to the cell to which they belong, and are numbered in sequence from the base towards the apex of the wing, for example, 1st, M_2: 2nd, M_2 and so on. A cell resulting from fusion between cells R and M, for example, becomes cell R+M.

The Abdomen. Except in the Pupipara, the abdomen is always clearly segmented. Each segment consists of a chitinized dorsal tergite, a less strongly chitinized ventral sternite, and on each side between tergite and sternite a pleural region, which is usually soft and membranous.

The external genitalia are carried on the posterior segments, and consist normally of three pairs of gonapophyses that in the female form the ovipositor, usually telescopic and withdrawn into the body when not in use. In higher insects, however, the ovipositor is formed from the last three segments of the abdomen. In the male there is an elongate penis, which may be paired. From near the base of the penis, a pair of processes arise, the parameres. Accessory copulatory organs, the claspers, are present in many males, but their origin is not always the same.

Internal Morphology

The Digestive System. (Fig. 6). This consists of the mouth, foregut, midgut, and hindgut. The alimentary system begins at the mouth, which contains the organs of feeding. The posterior portion of the mouth is the pharynx. The pharynx leads into an oesophagus, which continues through the thorax to the anterior portion of the abdomen. Here it enlarges to form the crop, which in those insects that eat solid food is followed by the gizzard. This organ is strongly muscular and is provided internally with grinding edges or teeth. In some insects the crop may be separate from the oesophagus, with which it communicates.

Salivary glands are present usually in the prothorax and open anteriorly by a pair of slender ducts that unite and open on the hypopharynx. Reservoirs for holding the saliva occur either as enlargements of the ducts or as separate chambers.

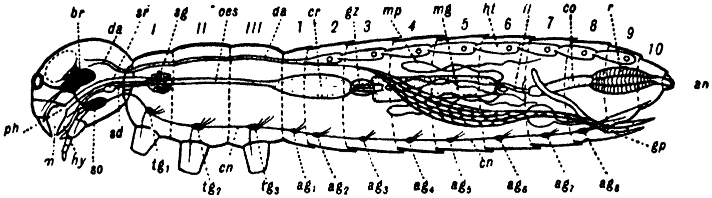

Fig. 6. Diagrammatic lateral view of internal organs of an insect, showing (*a*) alimentary and excretory system; (*b*) circulatory system; (*c*) central nervous system; I, II, III, the three thoracic segments; 1-10, the ten abdominal segments; ag_1-ag_8, the eight abdominal ganglia; *an.*, anus; *br.*, brain; *cn.*, connectives; *co.*, colon; *cr.*, crop; *da.*, dorsal aorta; *gp.*, gonopore; *gz.*, gizzard; *ht.*, heart; *hy.*, hypopharynx; *il.*, ileum; *m.*, mouth; *mg.*, midgut; *mp.*, Malpighian tubule; *oes.*, oesophagus; *ph.*, pharynx; *r.*, rectum; *sd.*, salivary duct; *sg.*, salivary gland; *so.*, sub-oesophageal ganglion; *sr.*, salivary reservoir; tg_1-tg_3, the three thoracic ganglia. The left ovary is unlabelled, with the duct opening at the gonopore (*gp.*).

(*After Tillyard.*)

The midgut comprises the stomach, into which the oesophagus opens by means of an oesophageal valve. The stomach is an elongate sac lined with large epithelial cells that secrete digestive juices. It may be a simple sac or provided with one or more diverticula. From its anterior end in some insects a fragile peritrophic membrane develops and surrounds the food. This protects the delicate gastric cells from damage by coarse food-particles, but permits digestion by osmosis. It is passed out with the faeces.

Following the midgut is the hindgut, which consists of the small intestine or ileum, the large intestine or colon, and the rectum, a large swollen chamber that reaches the exterior by the anus, situated between the tenth sternite and tergite.

The Excretory System. (Fig. 6 (*a*)). Excretion is carried out chiefly by the Malpighian tubules. These are slender, delicate tubules lying in the body cavity and opening into the alimentary tract at the junction of the midgut and hindgut. Their function is to extract uric acid from the blood. Groups of cells known as nephrocytes are also believed to assist in excretion. The most important of these are the pericardial cells, situated on either side of the heart. The fat-body that lines the body cavity not only stores up the nutrient products of digestion, but accumulates waste products such as urates.

The Respiratory System. The functions of respiration are performed by a system of air tubes or tracheae, which ramify through the body and open exteriorly by spiracles or stigmata. There are normally ten pairs of spiracles, two thoracic and eight abdominal. These spiracles have a thickened chitinous rim and lead into a chamber known as the atrium, from which one or more tracheae enter the body. Each trachea is a delicate flexible tube strengthened by spiral thickenings. They are much branched and end in fine tracheoles and minute capillaries that pass to every set of cells in the body.

The Circulatory System. (Fig. 6 (*b*)). This consists of a dorsal vessel or heart, situated mid-dorsally in the second to ninth abdominal segments. It is composed of eight chambers, each communicating with its neighbour in front by a pair of valves. Anteriorly it leads into the aorta, which runs forward to the front of the brain.

The circulatory system otherwise consists of the general body cavity, which is a haemocoele. The heart drives the blood forward towards the head, from whence it enters the haemocoele and baths all organs and tissues.

The blood consists of a liquid plasma containing several types of blood cells, the chief of which are the leucocytes, which are analogous to the leucocytes of vertebrates. There are no red blood cells. The principal function of the blood appears to be the reception of nutritive materials from the alimentary canal and their transfer either to the fat-body, where they are stored, or to tissues that require them. The blood also distributes oxygen that it receives from the capillaries of the respiratory system.

The Nervous System. (Fig. 6 (*c*)). The central nervous system is composed of a brain, or supra-oesophageal ganglion, a suboesophageal ganglion, and a series of paired ganglia situated ventrally in the thorax and abdomen and connected by a pair of longitudinal nerves. Fusion of some of the ganglia may occur, especially in the thorax. From each ganglion nerves pass to the heart, muscles, and other organs. The front of the head, pharynx, and oesophagus are served by the sympathetic nervous system.

The Reproductive System. In the male there is a pair of testes, each of which leads into a vas deferens, which may be provided with an enlargement, the seminal vesicle, in which the sperms are stored. These unite to form a common duct, which is equipped with an ejaculatory duct and leads into the penis. Accessory glands are present that probably secrete the seminal fluid.

In the female the ducts from the two ovaries, namely the oviducts (Fig. 6) unite to form the vagina. A spermatheca, in which the sperms are stored, and a pair of colleterial glands which secrete the sticky fluid used in laying the eggs, open into the vagina which leads into the ovipositor.

LIFE HISTORY

Eggs are usually deposited by the female after fertilization by the male, though some insects may be parthenogenetic. Each egg is composed of a large mass of yolk enmeshing its cytoplasm and enclosed in a delicate vitelline membrane, and finally covered by a tough shell, the chorion.

Hatching depends upon such external conditions as temperature and humidity. Subsequent development differs throughout the various orders.

The young in many insects differ from their parents only in size and in not being sexually mature. There is no metamorphosis in the various stages in the life cycle—each stage arises from the previous stage by an ecdysis or casting off of the skin.

In other insects metamorphosis is present but is incomplete. The larva, or the stage that emerges from the egg, differs somewhat from its parents, but gradually assumes parental form by a series of ecdyses. The immature stages invariably lack wings and other characteristics of the adult.

Finally, there are those insects in which metamorphosis is complete, the worm-like larvae being entirely unlike their parents. The next stage is the pupal or resting stage, which is usually inactive. It may be enclosed in a cocoon or in the hardened skin of the larva, the puparium. During the resting period the larval tissues are broken down and rebuilt into the structures of the adult, which emerges as soon as these are complete. The principal agents in this reconstruction are certain groups of cells known as imaginal buds or imaginal discs.

CLASSIFICATION

The class Insecta is divided into two subclasses (Apterygota and Pterygota) and twenty-three orders, which are listed below.

Sub-class APTERYGOTA

Insects that are entirely wingless and have never at any stage in their phylogenetic development possessed wings; one or more pairs of abdominal appendages are present, other than genitalia and cerci; metamorphosis completely absent.

Orders. THYSANURA (silver-fish and bristle-tails).
PROTURA.
COLLEMBOLA (spring-tails).

Sub-class PTERYGOTA

Insects that either possess wings in the adult stage or are descended from winged forms; no abdominal appendages present other than genitalia and cerci; metamorphosis more or less marked.

This subclass is subdivided into two divisions, namely, Ectopterygota or Hemimetabola, and Endopterygota or Holometabola.

Division Ectopterygota or Hemimetabola

Insects without a true pupal or resting stage; wings developing externally as buds; metamorphosis simple or slight.

Orders. EPHEMEROPTERA (may-flies).
ODONATA (dragon-flies).
ORTHOPTERA (cockroaches, crickets, grasshoppers).
ISOPTERA (termites or white ants).
DERMAPTERA* (earwigs).
PLECOPTERA or PERLARIA (stone-flies).
EMBIOPTERA (web-spinners).
PSOCOPTERA (book-lice).
ANOPLURA (biting lice, sucking lice).
THYSANOPTERA (thrips).
HEMIPTERA (bugs, leaf-hoppers, cicadas).

Division Endopterygota or Holometabola

Insects with a true pupal or resting stage; wings developing internally and larvae usually specialized: metamorphosis complete.

Orders. COLEOPTERA (beetles).
STREPSIPTERA.
HYMENOPTERA (bees, wasps).
NEUROPTERA (lacewings).
MECOPTERA (scorpion flies).
DIPTERA (true flies).
SIPHONAPTERA (fleas).
TRICHOPTERA (caddis-flies).
LEPIDOPTERA (butterflies, moths).

IMPORTANT ORDERS

The Odonata, Orthoptera, Isoptera, Anoplura, Hemiptera, Coleoptera, Hymenoptera, Diptera, Siphonaptera, and Lepidoptera contain insects of veterinary interest, the Anoplura, Siphonaptera, and Diptera possessing most of the more important forms.

Order ODONATA (Dragon-flies)

Medium to large, usually brilliantly coloured insects with large button-shaped eyes and short filiform antennae; two pairs of elongate wings with highly specialized venation, and usually a prominent thickening of the wing membrane between veins C and R (the pterostigma); abdomen long and narrow; adults occurring in the vicinity of water and predacious on other insects; immature stages aquatic.

In Europe, North America, and Manchuria dragon-flies, particularly species of *Libellula* and *Tetragoneuria*, are intermediate hosts for trematodes of the genus *Prosthogonimus*, which infect poultry (Fig. 7). These parasites are unknown in Australia.

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*A species of this order is an intermediate host of *Subulula brumpti*, a caecum worm of fowls in Hawaii.

Order ISOPTERA (Termites or White Ants)

Species living in densely populated societies consisting of winged and wingless sexual forms, and wingless sterile workers and soldiers; wings readily shed.

The only species of interest is *Macrohodothermes mossambicus transvaalensis*, which is the intermediate host of the poultry roundworm, *Harteria gallinarum*, in South Africa.

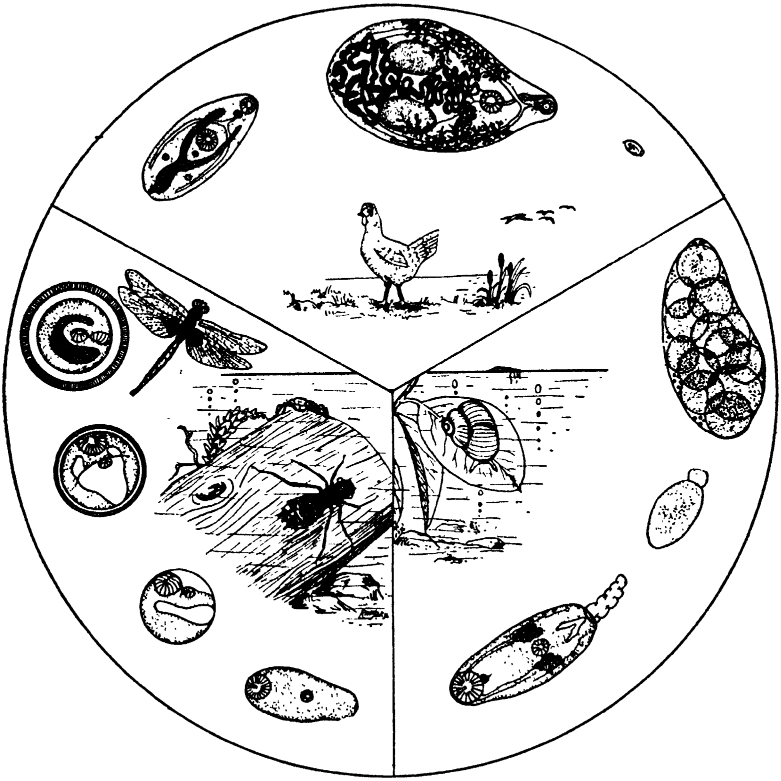

Fig. 7. The life cycle of the poultry oviduct fluke, *Prosthogonimus macrorchis*. (*After Macy.*)

Order ORTHOPTERA (Cockroaches, Crickets, Grasshoppers)

Small to large terrestrial insects, frequently with great powers of running or leaping; mouth-parts typically mandibulate; forewings of a tough and parchment-like consistency and, when at rest, covering the delicate hindwings; hindwings characterized by a widely expanding anal region, the anal fan.

The important insects in this order are found among the cockroaches and grasshoppers (p. 54 and Fig. 8). The eggs are laid in the ground or in a special receptacle, the ootheca (Fig. 30 (*d*), (*e*)), which is carried round by the female. The young on hatching are similar to the adult, but lack wings. There are six to eight instars, the wings appearing as small buds and increasing in size with each instar.

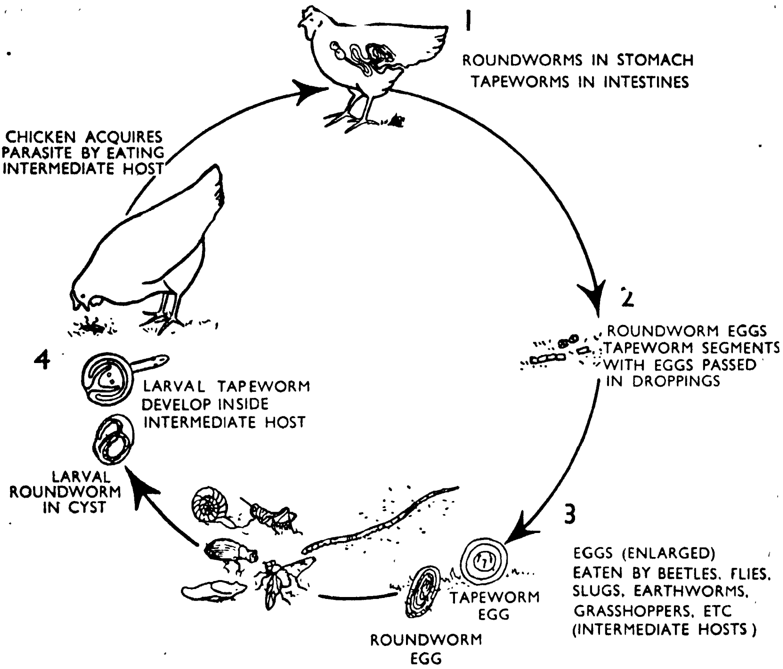

Fig. 8. Beetles and other insects as intermediate hosts of helminths infesting poultry.

(*After Buckley, Bunyea, and Cram.*)

Order HEMIPTERA (Bugs, Leaf-hoppers, Cicadas)

Mouth-parts constructed to form a rigid piercing and sucking proboscis, which is attached to the underside of the head and projects backwards beneath the body when at rest; mandibles and maxillae modified to form two pairs of slender stylets that rest in a groove in a segmented sheath, the labium; two pairs of wings usually present, the forewings being usually of tougher texture than the hindwings; immature stages similar in form to adult; six to eight instars, the wings gradually developing as backwardly projecting flaps.

The important species include the bed-bugs, *Cimex lectularius* Merritt (Fig. 32) and *C. hemipterus* (Fabr.), the former of which readily attacks poultry (pp.57-8); *C. columbarius* Jenyns, the pigeon bug of Europe and the United States; *Haematosiphon inodoros* Duges, which infests poultry in the south-west United States and Mexico; *Ornithocoris toledoi*, the chicken bug of Brazil; and species of *Triatoma*, *Belminus*, *Eratyrus*, and *Rhodnius*, the kissing bugs or assassin bugs of Central and South America, which transmit human trypanosomiasis in these regions. Equine encephalomyelitis may also be spread by *Triatoma sanguisuga* in the United States.

Order COLEOPTERA (Beetles)

Insects with two pairs of wings, the forewings modified into hardened covers or elytra, which fit very closely backwards over the body and protect the membranous hindwings; mouthparts adapted for biting; prothorax large and distinct from the rest of the thorax; metamorphosis complete.

The larva may be active and predatory, when it has a well-developed head and prominent prothoracic legs, or it may be sluggish and grub-like, when it feeds on vegetable matter. The pupa in most cases is without a cocoon, though some species cement pieces of wood or debris together or form an earthen cell. These insects are important, for many species, particularly the coprophagus species (p. 54), are intermediate hosts for helminth parasites (Fig. 8).

Order HYMENOPTERA (Bees, Wasps)

Insects with mouth-parts constructed for biting, but in many species specialized also for sucking and lapping; two pairs of membranous wings, the smaller hindwings interlocked with the forewings by a series of minute hooks, the two pairs being thus coupled together in flight; ovipositor modified for sawing, piercing, or stinging; metamorphosis complete, the pupae usually enclosed in a cocoon.

The important species include the bees, wasps, ants (p. 55) and a sawfly, *Platypsectra interrupta* (Klug) (p. 56).

Order LEPIDOPTERA (Butterflies, Moths)

Small to large, frequently beautifully coloured insects, with body, wings, and appendages clothed with broad scales; mouth-parts specialized to form a long, coiled, suctorial proboscis; metamorphosis complete, the larva or caterpillar with three pairs of short legs on the thorax and five pairs of prolegs on the abdomen; pupa naked or enclosed in a cocoon or earthen cell.

This order includes a few species that are harmful in the larval or pupal stages (p. 57).

Order SIPHONAPTERA (Fleas)

Small, parasitic, laterally compressed, wingless, insects; eyes, when present, simple; mouth-parts constructed for piercing and sucking; hindlegs very much longer than fore and middle legs, and adapted for jumping; metamorphosis complete.

Morphology (Fig. 9). The head is usually longer than high, with a rounded front. The antennae lie in a cavity or fossa on each side of the head, terminating in a large club divided into many small segments. The ventral border of the head may bear a row of strong spines, the genal comb or ctenidium. On the front margin of the head or frons there may be a small notch containing a minute tubercle, the frontal tubercle.

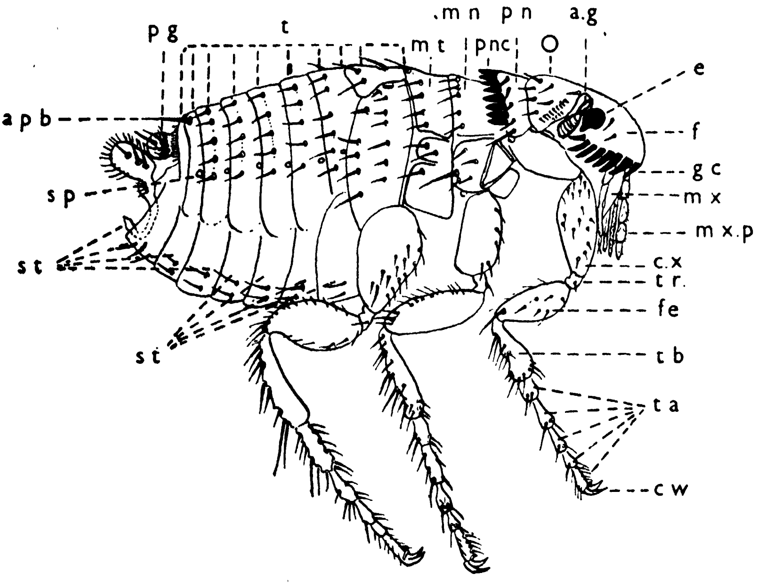

Fig. 9. The external structure of a flea (lateral view); *apb.*, antipygidial bristle; *a.g.*, antenna in antennal groove; *cw.*, claws; *cx.*, coxa; *e.*, eye; *f.*, frons; *fe.*, femur; *g.c..*, genal comb; *mn.*, mesonotum; *mt.*, metanotum; *mx.*, maxilla; *mxp.*, maxillary palp; *pg.*, pygidium; *pn.*, pronotum; *pnc.*, pronotal comb; *sp.*, spiracle; *st.*, abdominal sternites; *t.*, abdominal tergites; *ta.*, tarsi; *tb.*, tibia; *tr.* trochanter.

(*Redrawn from Patton and Craig.*)

The mouth-parts (Fig. 10) project downwards and consist of a pair of segmented maxillary palpi, a pair of labial palpi, a pair of very finely serrated mandibles, a single elongate labrum-epipharynx, and a pair of short, triangular maxillae. The skin is pierced by the mandibles and labrum-epipharynx. The mandibles placed together form a tube for the outflow of the salivary fluid, whilst the labrum-epipharynx plus the mandibles act as a channel up which the blood is sucked. The maxillae assist in maintaining the insect in position whilst feeding. The labial palpi form a protective tube for the three piercing organs when at rest.

The thorax (Fig. 9) is reduced, in some species very much so (Fig. 35). The posterior border of the pronotum may bear a row of strong backwardly projecting spines, the pronotal comb.

The legs (Fig. 9) have large flat coxae, small trochanters, elongate, strong femora, tibiae that broaden distally, and five-segmented tarsi, each of which ends in a pair of strong claws. The hindlegs are very long and their development in this direction gives the insect relatively enormous leaping powers. This specialization overcomes, to some extent, the lack of wings and enables the insect to reach its host.

The abdomen (Fig. 9) is comparatively large and is composed of ten segments, the last three being modified in both sexes in relation to the sex organs. The tergum of the ninth segment has a pitted area covered with small bristles, the pygidium. The female receptaculum seminis is chitinous in structure and sufficiently variable in shape as to be an excellent taxonomic structure. The male structures are very complicated and also of value in distinguishing closely related species.

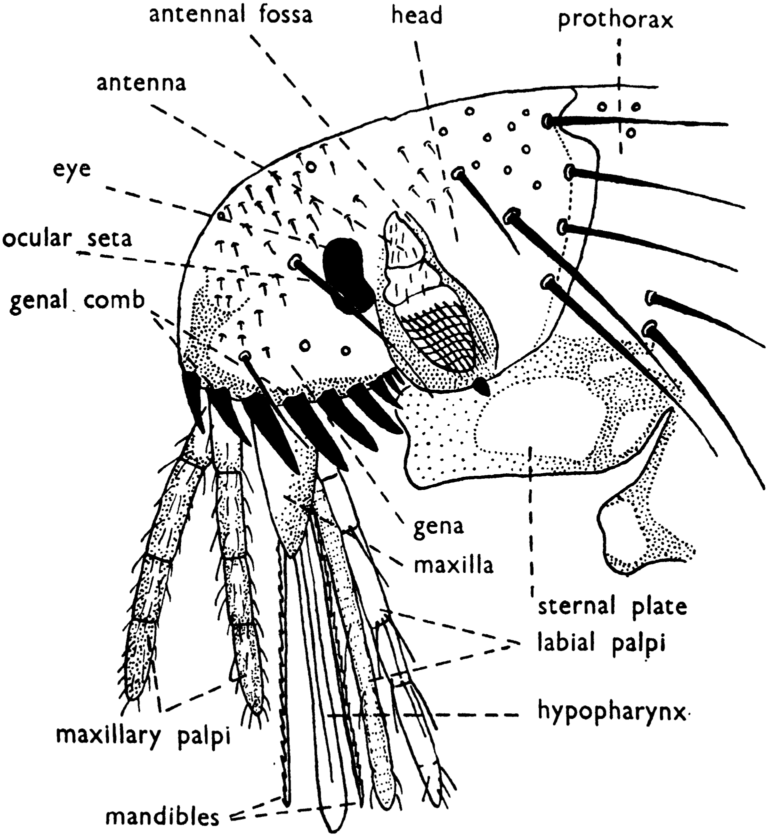

Fig. 10. Mouth-parts of flea, *Ctenocephalides canis* (lateral view). (*After Ewing.*)

Fleas Infesting Livestock. The species commonly found on domestic animals and poultry in Australia include the cat flea, *Ctenocephalides felis* (Bouché), the dog flea *C. canis* (Curtice), the human flea, *Pulex irritans* Linn., the chicken flea, *Ceratophyllus gallinae* Schrk., and the stickfast fleas, *Echidnophaga gallinacea* Westw., *E. myrmecobii* Waterh., and *E. perilis* Jordan. These may be distinguished by the following key:

Key to the Fleas Infesting Livestock in Australia

1. Thorax much reduced, the three thoracic segments together much shorter than the first abdominal segment............Family Tungidae (Fig. 35) 2
   Thorax normal, not reduced, the three thoracic segments together much longer than the first abdominal segment.........Family Pulicidae (Fig. 9) 4

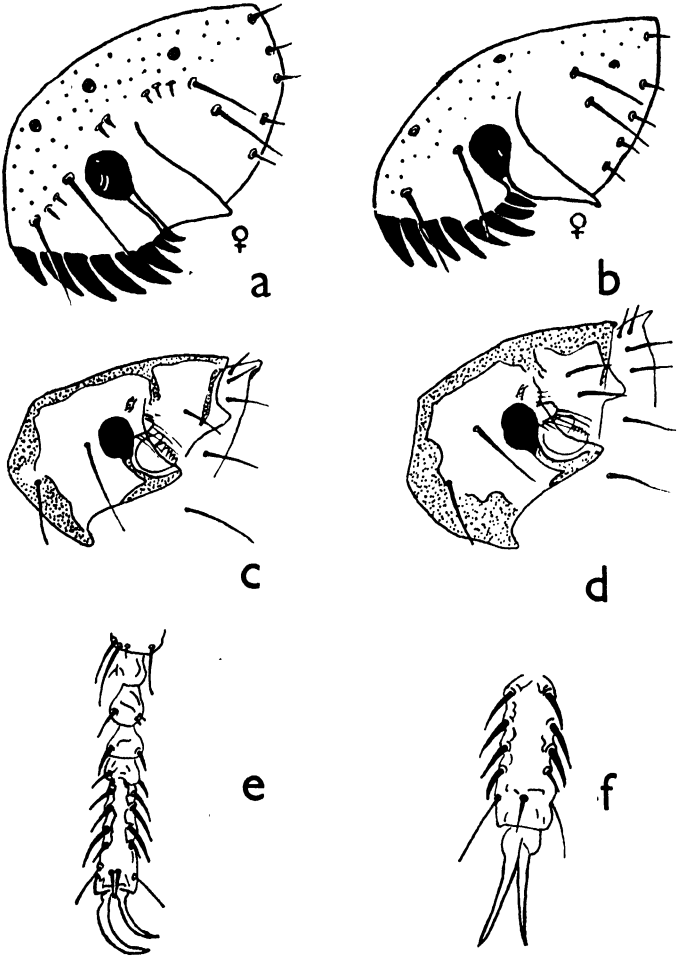

Fig. 11. (*a*) Head of *Ctenocephalides canis*, female (lateral view); (*b*) head of *C. felis*, female (lateral view); (*c*) head of *Echidnophaga perilis*, female (lateral view); (*d*) head of *E. gallinacea*, female (lateral view); (*e*) tarsus of *E. gallinacea* (ventral view); (*f*) tarsus of *E. myrmecobii* (ventral view).

(*Figs* (*a*), (*b*) *after Hubbard;* (*c*), (*d*), (*e*), (*f*) *after McCulloch*)

2. One apical ventral bristle on the fifth tarsal segment of all legs.............. *Echidnophaga myrmecobii* (p. 60 and Fig. 11 (*f*))
   Two apical ventral bristles on the fifth tarsal segments of all legs 3
3. Occiput with two bristles............ *E. gallinacea* (p. 63 and Fig. 11 (*d*), (*e*))
   Occiput with one bristle ....*E. perilis* (p. 60 and Fig. 11 (*c*))
4. No genal or pronotal comb; mesosternite without a rod-like thickening ....*Pulex irritans* (p. 60)
   Genal and/or pronotal comb present..
5. Only pronotal comb present, four to six bristles on inner surface of hind femur...*Ceratophyllus gallinae* (p. 63)
   Both genal and pronotal combs present... 6
6. Frontal spine of genal comb as long as the second spine; head with low sloping front and usually about twice as long as high........................ ....*Ctenocephalides felis* (p. 60 and Fig. 11 (*b*))
   Frontal spine of genal comb shorter than the second spine; head with rounded front, and only one and a half times as long as high........... ....*C. canis* (p. 60 and Fig. 11 (*a*))

The species mentioned in this key are, with the exception of *E. myrmecobii* and *E. perilis*, all introduced. It is only very rarely that other native fleas are encountered on domestic animals. *Pygiopsylla congrua* Roth., normally found on the water rat, *Hydromys chrysogaster*, has, for example, been seen on one occasion on the dog. Rat fleas may sometimes be seen on dogs and cats, for example, *Xenopsylla cheopis* (Roth.), *Nosopsyllus fasciatus* (Bosc.) and *Leptopsylla segnis* (Shrönh.). *X. cheopis* closely resembles *Pulex irritans*, but may be distinguished by the presence of a rod-like thickening of the mesosternite (Fig. 12). It is common on

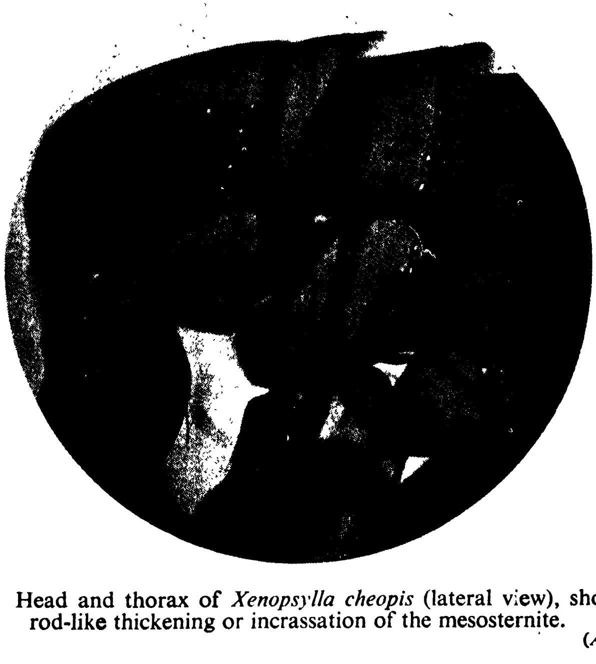

Fig. 12. Head and thorax of *Xenopsylla cheopis* (lateral view), showing the rod-like thickening or incrassation of the mesosternite.

(*After Keith.*)

rats in Australia, and is a notorious vector of urban or epidemic bubonic plague (*Pasteurella pestis*) in man in many parts of the world, though in some countries, for example, India and Africa, this role is assumed by *X. astia* and *X. braziliensis*. *Pulex irritans*, *C. felis*, *C. canis*, *N. fasciatus*, *L. segnis*, and other species may also carry this disease experimentally, but are not regarded as important natural vectors.

The sylvatic type of bubonic plague is carried by species of fleas that infest certain wild rodent reservoir hosts. *P. irritans* and *C. canis* have also been incriminated as vectors of salmonellosis (*Salmonella enteriditis*) in man. Murine typhus (*Rickettsia prowazeki typhi.*) is spread by different species of fleas from rat to rat and from rat to man. *X. cheopis* is most commonly concerned. What appears to be the same species of *Rickettsia* occurs in dogs and cats in the Mediterranean region.

Order ANOPLURA (Lice)

Small insects with the body flattened dorso-ventrally; without ocelli and wings; mouth-parts adapted either for biting or piercing; the three segments of the thorax free or fused, or only the prothorax may be free; legs stout and formed for running and clinging; immature stages similar to the adults.

Morphology (Fig. 13 (*a*), (*b*)). The portion of the head anterior to the antennae is the forehead, the clypeus forming its anterior margin, and sometimes separated from the rest of the head by the clypeal suture. Short chitinous projections, the trabeculae may be present immediately in front of the antennae. The postero-lateral corners of the head are the temples and the posterior portion of the head between the corners is the occiput. The antennae are typically five-segmented, sometimes reduced to four or three segments, situated laterally, and may be concealed partly or wholly in excavations, the antennal fossae. Eyes, when present, are compound, and are situated behind the antennae.

The mouth-parts may be ventral and mandibulate or terminal and formed for piercing and sucking.

The three segments of the thorax may be free or fused together; in some genera only the mesothorax and the metathorax are fused. Ventrally a sternal plate, which may be divided, is often present between the coxae of the legs.

The legs are short and strong and in some species may be modified into claspers for grasping the hairs. The tarsi are one- or two-segmented and usually terminate in one or two strong claws. Wings are entirely missing.

The abdomen is oval in shape, sometimes very broad, and has eight or nine visible segments. Each segment may be provided with a dorsal or tergal plate and a ventral or sternal plate, and sometimes with lateral or pleural plates as well. There are usually six pairs of spiracles, which open laterally on segments II to VII or III to VIII. Like the rest of the body, the abdomen is provided with numerous setae, some of which may be arranged in rows across the segments.

The male has a chitinous penis and well-developed parameres on the posterior end of a basal plate. The female is provided with a subgenital plate, and frequently also with a pair of gonapophyses.

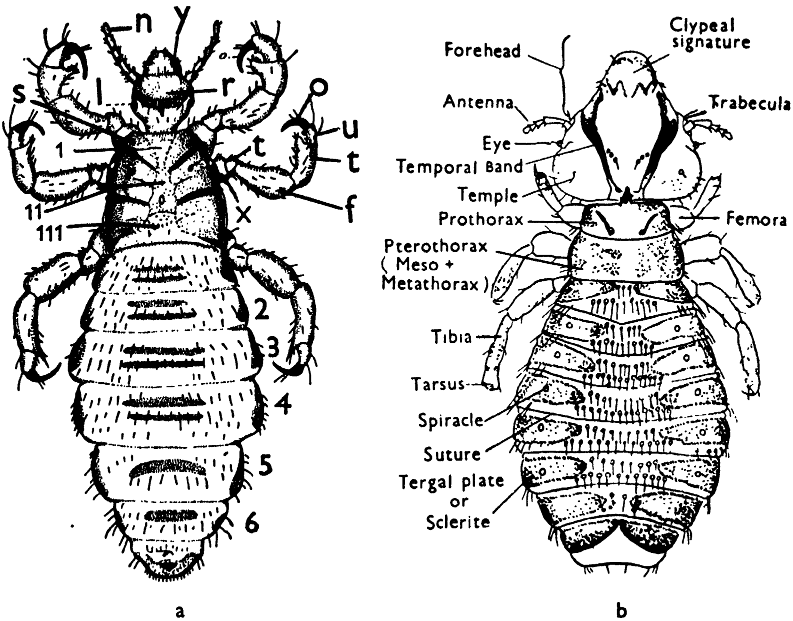

Fig. 13. (*a*) Structure of a male sucking louse; *n*., antenna; *y*., clypeus; *r*., frons; *l*., eye; *o*., claw; *u*., tarsus; *t*., tibia; *f*., femur; *t*., trochanter; *x*., coxa; *s*., thoracic spiracle; I, prothorax; II, mesothorax; III, metathorax; 1-6, abdominal segments; (*b*) structure of a biting louse.

(*Fig.* (*a*) *after Keilin and Nuttall; Fig.* (*b*) *after Bedford.*)

Classification. Two suborders are recognized, the Mallophaga or biting lice, in which the mouth-parts are constructed for chewing, and the Siphunculata or sucking lice, which have piercing and sucking mouth-parts.*

Sub-order MALLOPHAGA. The biting lice live on scales, scurf, feathers, etc., on the skin surface. The mouth-parts are ventral in position and consist of a pair of mandibles with a sharp apical tooth, a pair of maxillae frequently provided with palpi of four segments or less, and a reduced labium without palpi. The prothorax is free, but the mesothorax and metathorax are frequently fused. The tarsi may have either one or two segments, and the claws are single or paired. This sub-order reaches its highest development on birds, but also includes a number of species infesting mammals.

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* The most recent classification places lice in the order Phthiraptera, with three suborders: the Mallophaga or biting lice, the Anoplura or sucking lice, and the Rhynchophthirina, which includes the single genus *Haematomyzus*, which infests elephants.

Sub-order SIPHUNCULATA. Sucking lice are confined to mammals, and live on the blood and fluids of the host. The mouth-parts are terminal, retractile, and concealed when not in use. They consist of three stylets, one dorsal, one intermediate, and one ventral. The ventral stylet is the piercing organ and forms a long, narrow gutter in which the other two stylets rest. The dorsal stylet forms a tube that is the food canal, and the intermediate stylet is very slender, the salivary duct opening at its base. The cuticle of the host is wounded by a circlet of teeth surrounding the mouth orifice, the ventral stylet being then inserted until a blood vessel is reached.

The three thoracic segments are fused together. The tarsi consist of a single segment and there is only one claw.

A large number of lice infest domestic animals and birds, and are important chiefly because of the irritation they cause. They are rarely concerned in the transmission of disease and in this respect differ from the human lice. The human body louse, *Pediculus humanus corporis*, transmits epidemic typhus (*Rickettsia prowazeki*), trench fever (*R. quintana*) and also relapsing fever (*Borrelia recurrentis*). The human head louse, *P. humanus capitis*, is an experimental vector of *R. prowazeki*. Tularaemia (*Pasteurella tularensis*) may be transmitted from rabbit to rabbit by *Haemodipsus ventricosus* and from mouse to mouse by *Polyplax serrata*.

KEY TO THE LICE INFESTING LIVESTOCK IN AUSTRALIA

1. On cattle 2
   On sheep 7
   On horses 9
   On goats 10
   On pigs .... *Haematopinus suis* (p. 74 and Fig. 44)
   On dogs 11
   On cats .... *Felicola subrostrata* (p. 85 and Fig. 55)
   On poultry 13

2. Mouth-parts ventral and constructed for chewing; head much broader than the thorax .... *Damalinia bovis* (p. 67 and Fig. 38)
   Mouth-parts terminal and constructed for piercing and sucking; head not as broad as the thorax 3

3. Forelegs equal in size to the midlegs and hindlegs 4
   Forelegs smaller than the midlegs and hindlegs 6

4. Pleural angles of abdomen with two bristles 5
   Pleural angles of abdomen with five or more bristles... *H. tuberculatus* (p. 68)

5. Lateral projections of the sternal plate in both sexes very acute, the median projection in the male very long .... *H. quadripertusus* (p. 70 and Fig. 14 (*a* - *c*))
   The sternal plate frequently difficult to detect, its lateral and median projections not pronounced... *H. eurysternus* (p. 69 and Figs 14 (*d*), (*e*), 41)

6. Head much longer than broad, abdominal tergites with two rows of setae .... *Linognathus vituli* (p. 68 and Fig. 39)
   Head about as long as broad, abdominal tergites with a single row of setae, abdominal spiracles situated on tubercles .... *Solenopotes capillatus* (p. 69 and Fig. 40)

7. A biting louse .... *D. ovis* (p. 75 and Fig. 37)
   A sucking louse 8

8. Head about as long as wide; abdomen thickly beset with bristles with no obvious arrangement in rows......*L. pedalis* (p. 76 and Figs 15 (*a*), 46)
Head longer than wide; bristles on abdomen arranged in two well-defined rows ....*L. ovillus* (p. 77 and Figs 15(*b*), 47)

9. A biting louse....................................*Bovicola equi* (p. 72 and Fig. 42)
A sucking louse...................................*H. asini* (p. 73 and Fig. 43)

10. A biting louse..................................*D. caprae* (p. 82 and Fig. 50)
A sucking louse..................................*L. stenopsis* (p. 82 and Fig. 51)

11. A sucking louse.................................*L. setosus* (p. 84 and Fig. 54)
Biting lice.. 12

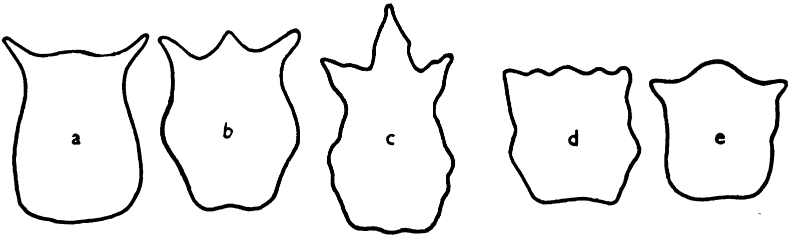

Fig. 14. Sternal plates of *Haematopinus eurysternus* ((*d*) and (*e*)), and of *H. quadripertusus* (female (*a*) and (*b*); male (*c*)).

12. Head triangular with a pair of large ventral spines.......................... ....*Heterodoxus longitarsus* (p. 84 and Fig. 53)
Head more or less quadrangular, no such spines............................ ....*Trichodectes canis* (p. 84 and Fig. 52)

13. Antennae swollen towards their apices and, when at rest, largely concealed in grooves; maxillary palpi present.................................. 14
Antennae filiform and always exposed; maxillary palpi missing........... 16

14. Thorax very large, the mesonotum unusually so, and divided from the metanotum by a distinct groove—

(*a*) on goose ....*Trinotum anserinum* (p. 90)
(*b*) on duck ....*T. querquedulae* (p. 91)

Thorax normal; mesonotum and metanotum united.......................... 15

15. Forehead with a pair of large spine-like processes on venter beneath bases of palpi; abdomen with two rows of setae; on fowl and turkey ....*Eomenacanthus stramineus* (p. 88 and Fig. 61)
Forehead without such spines; abdomen with one row of setae; on fowl and turkey............................*Menopon gallinae* (p. 88 and Fig. 60)

16. Forehead with a narrow marginal band; clypeal suture and plate (signature) absent.. 17
Forehead without a complete or almost complete marginal band; clypeal suture and plate usually present.. 19

17. Temples rounded—

(*a*) on fowl...........*Lipeurus heterographus* (p. 86 and Fig. 57)
(*b*) on fowl...............................*L. caponis* (p. 86 and Fig. 56)
(*c*) on turkey...................................*L. gallipavonis* (p. 89)

Temples angulate.. 18

18. Third segment of male antenna with an appendage—
    (*a*) on fowl.....................*Goniodes dissimilis* (p. 87 and Fig. 58)
    (*b*) on pigeon..*G. damicornis* (p. 91)
    (*c*) on turkey..................*Goniodes meleagridis* (p. 89 and Fig. 62)
  Third segment of male antenna without an appendage—
    (*a*) on fowl.....................*Goniocotes gallinae* (p. 87 and Fig. 59)
    (*b*) on fowl..*G. gigas* (p. 87)

19. A short, broad species; a pair of small peg-like spines dorsally behind clypeal suture; on ducks.........*Anatoecus dentatum* (p. 90 and Fig. 64)
  Elongate and narrow species... 20

20. Clypeus with two pairs of spines on dorsum; on pigeon.................... ....*Columbicola columbae* (p. 91 and Fig. 65)
  Clypeus without such spines—
    (*a*) on goose............................*Esthiopterum anseris* (p. 90)
    (*b*) on duck.............................*E. crassicorne* (p. 90 and Fig. 63)

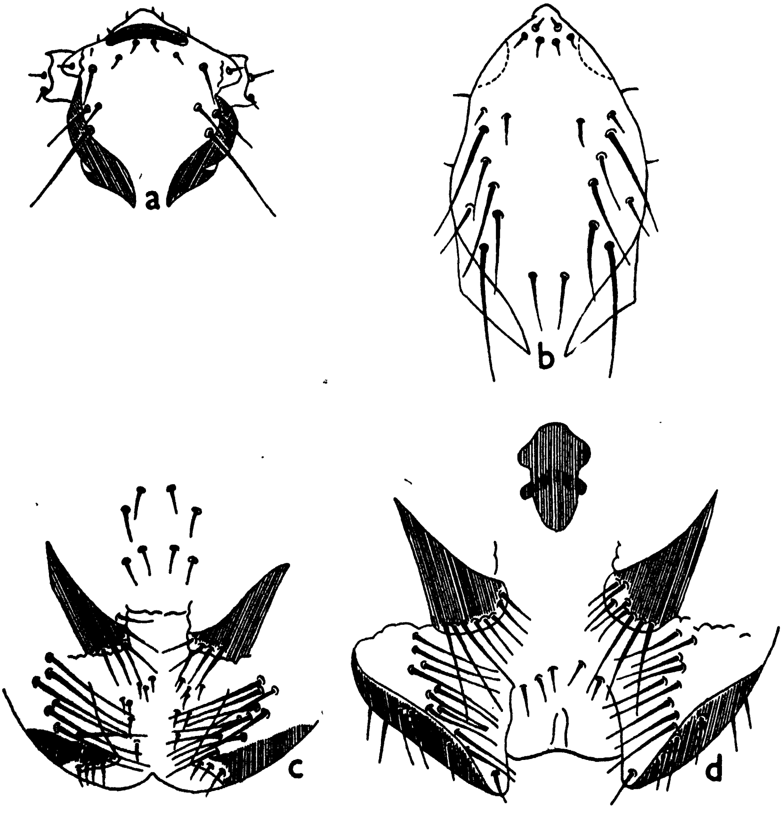

Fig. 15. Head (dorsal view) and apical abdominal segments (ventral view) of *Linognathus pedalis* (female (*a*) and (*c*)), and of *L. ovillus* (female (*b*) and (*d*)).

(*Redrawn from Ferris.*)

Order DIPTERA (True Flies)

Small to moderate-sized insects, typically with one pair of wings; forewings membranous with narrow bases, the venation open with few or no cross-veins; hindwings modified into halteres; mouth-parts forming a proboscis, suctorial and terminating in fleshy lobes or sometimes adapted for piercing; mesothorax strongly developed; metamorphosis complete.

Morphology. The head is provided with a pair of large compound eyes, which may be holoptic or close together in the male and dichoptic or widely separated in the female. The antennae which are of considerable importance in the classification of the order, are composed of a basal scape, a pedicle, and a variable number of segments, the flagellum. In the higher forms the flagellum is represented by a third segment that may bear a jointed appendage, the style. When bristle-like, this appendage is known as an arista. In the suborder Cyclorrhapha a frontal suture is present, an inverted U-shaped groove that surrounds the antennae and marks the position of the ptilinum, a pulsating bladder that assists the insect to escape from the puparium and is later withdrawn into the head. Just above the bases of the antennae in this suborder there is a small crescentic sclerite, the frontal lunule (Fig. 16 (*a*)).

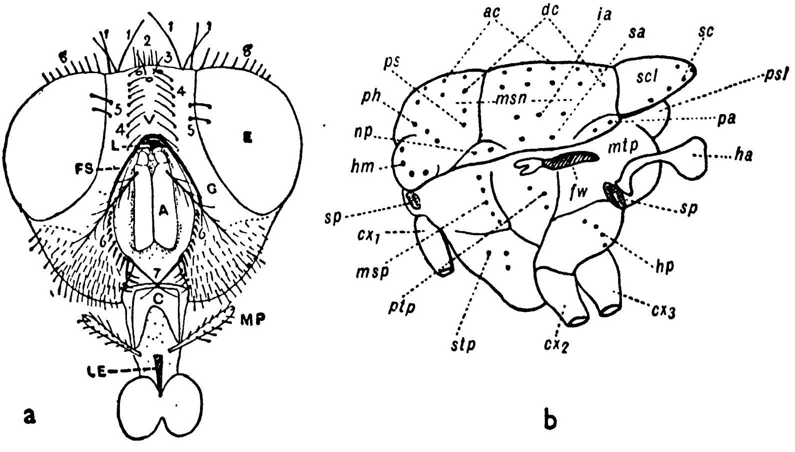

Fig. 16. (a) Head of cyclorrhaphous fly (frontal view); *A.*, antenna; *B.*, clypeus; *E.*, eye; *FS.*, frontal suture; *G.*, gena; *L.*, frontal lunule; *LE.*, labrum-epipharynx; *MP.*, maxillary palp; *V.*, vertex; 1, cephalic bristles; 2, post-vertical bristles; 3, ocellar bristles; 4, frontal bristles; 5, fronto-orbital bristles; 6, facial bristles; 7, oral vibrissae; 8, post-orbital bristles. (b) Thorax of cyclorrhaphous fly (lateral view); *ac.*, acrostichal bristles; *cx.*, coxa; *dc.*, dorso-central bristles; *fw.*, forewing (cut off); *ha.*, haltere; *hp.*, hypopleuron and hypopleural bristles; *hm.*, humerals; *ia.*, inter-alars; *msn.*, mesonotum; *msp.*, mesopleuron and mesopleural bristles; *mtp.*, metapleuron; *np.*, notopleural bristles; *pa.*, post-alars; *ph.*, post-humerals; *ps.*, presulturals; *psl.*, post-scutellum; *ptp.*, pteropleuron and pteropleural bristles; *sa.*, supra-alars; *sc.*, scutellars; *scl.*, scutellum; *sp.*, spiracle; *stp.*, sternopleuron and sternopleural bristles.

(After Tillyard and Tonnoir.)

The mouth-parts project beneath the head in the form of a proboscis and have become highly specialized for the function of sucking or piercing. The proboscis in the sucking species is a tubular structure that ends in a pair of swollen lobes, the labella. These possess a pseudotracheal membrane consisting of a series of small channels, each supported by a number of chitinous rings. This membrane acts as a filtering apparatus, permitting only very fine particles of food to be sucked up. The food eventually reaches the mouth cavity or stomodaeum via a large channel that traverses the proboscis, suction being provided both by the mouth cavity and by accessory structures in the head.

Along the dorsal aspect of the proboscis lies a groove or gutter, the labial gutter, in which lie the labrum-epipharynx, hypopharynx, and first maxillae. The labrum-epipharynx is formed from the union of the labrum and epipharynx and is elongate and grooved ventrally. The hypopharynx is slender and is applied to this groove to form a food channel. This communicates distally with the large channel into which the pseudotracheal channels lead at the prestomum.

In the biting forms included in the Culicidae, Simuliidae, Psychodidae, Ceratopogonidae, and Tabanidae the first maxillae and mandibles are elongate and spear-like and are used as cutting and piercing organs. In the Muscidae, which includes the house-fly and its allies, and in the Calliphoridae or blowflies, these organs have entirely disappeared. In the biting species of the Muscidae the act of biting is carried out by special teeth-like structures, the prestomal teeth, at the distal end of the proboscis.

In all Diptera the salivary duct opens at the tip of the hypopharynx.

The thorax (Fig. 16(*b*)) consists chiefly of the mesothorax, which comprises practically all the visible dorsal and lateral parts. Its mesonotum is large and is separated from the scutellum by a distinct groove. The head and thorax bear many bristles, the number and arrangement of which are of great value in the recognition of various species.

The forewings are attached to the mesonotum, and have a strong costal margin that is thickened to and sometimes beyond the wing apex. The venation is variable and cross-veins are few.

The hindwings are represented by a pair of delicate knobbed structures, the halteres, which are considered to assist in maintaining balance during flight. In the higher forms the halteres are each covered by two scale-like processes, the calypteres or squamae, the inner one being immobile, the outer one moving with the wing.

In a few species the forewings and sometimes also the halteres are missing.

The legs are usually slender, the hind pair being the longest. The tarsi are five-segmented and each tarsus ends in two strong claws. A single median pad or bristle, the empodium, and a pair of pad-like pulvilli beneath the claws may be present (Fig. 4).

The abdomen is usually sub-cylindrical in shape, but may be somewhat swollen or even flattened. It is composed of ten or eleven segments, but usually only four or five segments are apparent. The terminal segments are modified in connection with the specialized copulatory apparatus of the male, the hypopygium, and with the telescopic ovipositor in the female.

Habits and Life History. The eggs may be deposited in a wide variety of situations, such as mud, sand, water, decaying vegetable and animal matter, and even on living flesh. In some forms the females may deposit fully developed eggs that immediately hatch (ovivivaparous), and in others they may give birth to fully grown larvae (viviparous).

The larva is elongate and cylindrical. Thoracic legs are absent, but abdominal processes or prolegs may be present. The head may be well developed, greatly reduced and retracted, or even absent. Mouth-parts are mandibulate or vestigial. Larvae without any visible head are called maggots.

When fully grown the larvae enters the pupal or resting stage. This stage may have all the appendages soldered to the body and be enclosed in a thin sheath. In such pupae the abdomen may retain considerable freedom of movement. In the higher forms the larva contracts and pupates inside the larval cuticle, which hardens to form a barrel-like puparium.

Classification. Three suborders are recognized, Nematocera, Brachycera, and Cyclorrhapha.

Sub-order NEMATOCERA

Small delicate flies with the adult antennae consisting of eight to sixteen segments, the majority of the segments alike and without an arista; palpi pendulous, four- or five-segmented; discal cell (1st M_2) usually absent, cubital cell (Cu_1) when present, widely open; larva with a well-developed head and horizontally biting mandibles; pupa free.

Of the thirteen families only the Psychodidae, Culicidae, Simuliidae, and Ceratopogonidae contain species associated with livestock.

Sub-order BRACHYCERA

Adult antennae usually three-segmented, the last segment elongate; arista or style terminal when present; palpi porrect, one- or two-segmented; discal cell (1st M_2) usually present, cubital cell (Cu_1) contracted before the wing margin or closed; larva with head incomplete and retractile and vertically biting mandibles; pupa free.

There are fourteen families in this suborder, but only the Tabanidae is of veterinary interest. The Leptidae contains a few biting flies belonging to the genus *Spaniopsis*. These resemble tabanids, but have a very short proboscis and a narrow head. They can be very annoying to man, but their relationship to livestock is unknown.

Sub-order CYCLORRHAPHA

Adult antennae three-segmented, the arista usually dorsal; palpi one-segmented; head with a frontal lunule and usually a ptilinum (Fig. 16); discal cell (1st M_2) almost always present, cubital cell (Cu_1) contracted or closed; larval head vestigial (maggot); pupa in a barrel-like, immobile puparium. There are two sections, the Aschiza and Schizophora.

Section Aschiza

Ptilinum absent and frontal suture obscure or restricted; frontal lunule often indistinct or absent.

The section does not contain any flies of veterinary importance.

Section Schizophora

Frontal suture and lunule distinct; ptilinum always present.

Here are included the families Muscidae (the house-fly, bush-fly, stable fly, tsetse fly and buffalo fly), Calliphoridae (the blowflies), and Oestridae (the bot-flies).

Section Pupipara

Ectoparasitic, flattened, leathery flies with an unsegmented abdomen and with the body and legs constructed for clinging to their host and moving among the hair or feathers; wings often reduced or absent; larvae deposited when fully grown and ready to pupate.

This section contains the spider flies or louse-flies, such as the sheep ked, and the horse louse-fly, which belong to the family Hippoboscidae.

Key to the Important Families of Diptera Affecting Livestock

1. Small, usually delicate flies; antennae composed of eight to sixteen segments; maxillary palpi with four or five segments; vein Cu_1 not converging towards vein A_1 distally 2
   More robust and larger flies; antennae three-segmented, the third segment sometimes with four to eight annulations; maxillary palpi with one or two segments; vein Cu_1 strongly converging towards vein A_1 distally or fusing with it 5
2. Small hairy moth-like flies; M with four branches, R with five branches .... PSYCHODIDAE (Sandflies)
   Not such flies 3
3. Body, its appendages and wing veins densely clothed with scales; Rs and M forked, R_{4+5} straight and running between them .... CULICIDAE (Mosquitoes)
   Not such flies 4
4. Very small flies, antennae plumose or pilose, with twelve to fifteen segments; wings sometimes spotted and always provided with a wing fringe .... CERATOPOGONIDAE (Sandflies)
   Small, but more robust flies; antennae bare with ten or eleven segments; anterior wing veins thickened and carrying bristles .... SIMULIIDAE (Black-flies)
5. Large blood-sucking flies without bristles; the third antennal segment with four to eight annulations .... TABANIDAE (March-flies)
   Bristles present on body; third antennal segment not annulated 6
6. Mouth-parts rudimentary, proboscis absent .... OESTRIDAE (Bot-flies)
   Mouth-parts visible and in the form of a proboscis 7
7. Head and thorax closely united; abdomen not segmented; flattened leathery flies; wings present or absent .... HIPPOBOSCIDAE (Louse-flies)
   Head and thorax normal; abdomen segmented; body not flattened or leathery; wings always present 8
8. Hypopleura with bristles, one convex area below the scutellum .... CALLIPHORIDAE (Blowflies)
   Hypopleura without bristles ..... MUSCIDAE (House-fly, stable fly, etc.)

Sub-order NEMATOCERA

Family PSYCHODIDAE (Sandflies)

Small hairy moth-like flies, the wings, body, and legs thickly covered with long hairs and sometimes scales; antennae with sixteen bead-like segments; wings with many longitudinal veins, R having five branches and M four branches (Figs. 17, 66).

The members of this family are for the most part harmless, but the subfamily Phlebotominae (p. 93) contains a number of species that bite and suck blood and are important vectors of disease.

Species of *Phlebotomus* are very small flies, only 1.5 to 3.5 mm. in length. They may be distinguished from other species of the Psychodidae by the following characters:

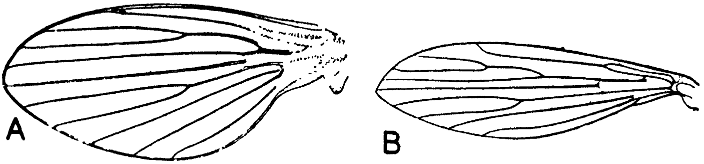

Fig. 17. Wing of (*a*) *Perichoma* (Psychodinae); (*b*) *Phlebotomus* (Phlebotominae). (Not to same magnification.)

(*After Smart.*)

1. The wings are elongate and relatively narrow and when at rest are held away from the body. In other psychodids the wings are much broader and when at rest are held over the body in a roof-like manner.
2. The vein R_{2+3} arises from Rs nearer the middle of the wing than the base (Fig. 17).
3. The mouth-parts are adapted for piercing.

Family CERATOPOGONIDAE (Sandflies)

Minute blood-sucking flies; antennae composed of twelve to fifteen segments (Fig. 18 (*a*)), plumose in the male, pilose in the female; mouth-parts extending as a piercing organ ventrally from the head; thorax strongly arched (Fig. 67 (*a*)); wings provided with microtrichia and macrotrichia and a wing fringe, frequently ornamented with dark spots, venation much reduced, the anterior veins more marked than the posterior veins (Fig. 18 (*b*)); larva terrestrial or aquatic.

These tiny flies are extremely annoying to man and to livestock. Some species are intermediate hosts of important roundworm parasites of animals and one species is a vector of a serious virus disease of sheep (p. 94).

Family SIMULIIDAE (Black-flies, Buffalo Gnats)

Small robust, hump-backed flies (Fig. 68 (*a*)); antennae short with ten to eleven segments, rarely nine, without hairs at the joints; palpi four-segmented, and longer in the female than in the male; proboscis short and stout, constructed for piercing (Fig. 19 (*a*)); wings short and broad, the anterior veins much thickened and carrying short bristles,

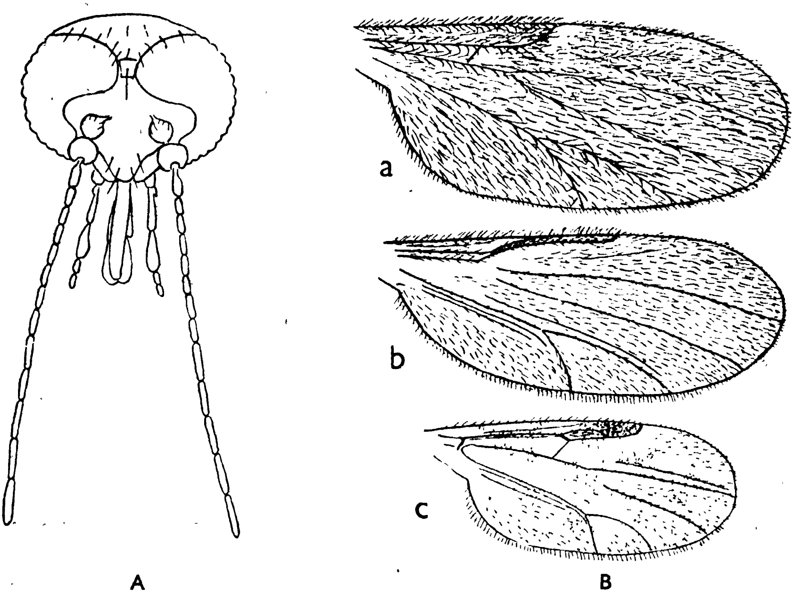

Fig. 18. A. Head (anterior view) of a ceratopogonid fly (*Culicoides*). B. Wings of ceratopogonid flies: (*a*) *Forcipomyia*; (*b*) *Lasiohelea*; (*c*) *Culicoides*.

(*After Lee.*)

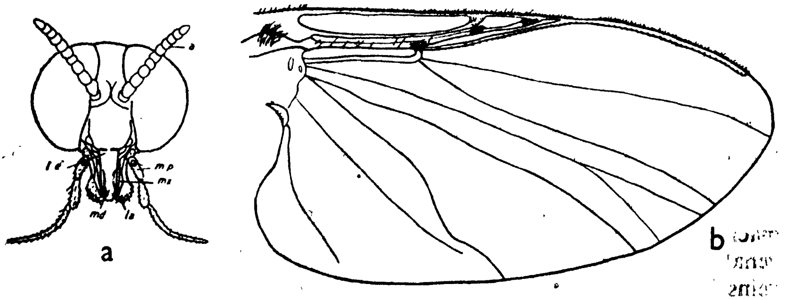

Fig. 19. (*a*) Head of simuliid fly (frontal view); *a.*, antenna; *la.*, labium; *l.e.*, labrum-epipharynx; *md.*, mandible; *mp.*, maxillary palp; *mx.*, maxilla; (*b*) wing of simuliid fly, *Austrosimulium mirabile.*

(*Fig.* (*a*) *after Gibbons; Fig.* (*b*) *after Mackerras.*)

remaining veins few and poorly developed (Fig. 19 (*b*)); legs short; larvae aquatic in running water.

Black-flies are severely irritating pests of man and beast throughout the world. Several species are intermediate hosts of important roundworm parasites (p. 96).

Family CULICIDAE (Mosquitoes)

The subfamily Culicinae is the only one of medical or veterinary importance.

Sub-family Culicinae

Slender delicate flies, with legs, palpi, and in most cases the body, covered with scales, which are also present along the wing veins and form a well-defined wing fringe (Fig. 71); proboscis elongate and constructed for piercing (Fig. 20 (*c*)); antennae consisting of fifteen segments, plumose in the male, pilose in the female (Fig. 20 (*a*), (*b*)); wings narrow and elongate and when at rest folded flat along the abdomen, a number of longitudinal veins present; Rs and M forked and between them runs the straight vein R_{4+5} (Fig. 20 (*d*)); larvae and pupae aquatic.

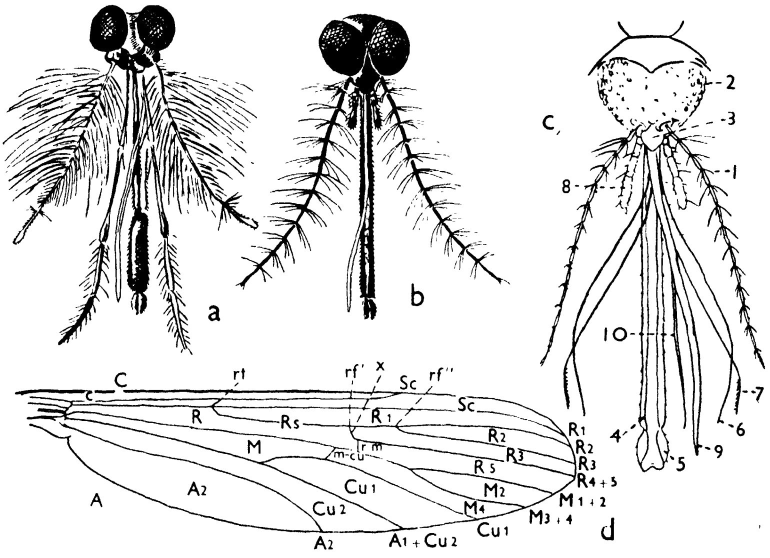

Fig. 20. (*a*) Head of male mosquito; (*b*) head of female mosquito; (*c*) mouthparts of female mosquito; 1, antenna; 2, compound eyes; 3, clypeus; 4, labium; 5, labellum; 6, mandibles; 7, maxilla; 8, maxillary palpi; 9, labrum-epipharynx; 10, hypopharynx; (*d*) wing of mosquito.

(*Figs* (*a*), (*b*), (*c*) *after Herms; Fig.* (*d*) *after Patton.*)

Classification. There are two main groups or tribes, the Anophelini and the Culicini.

Tribe Anophelini

In anopheline mosquitoes the palpi of the male and female are long, equal in length to or longer than the proboscis. When resting or biting the adults form an angle with the surface, the body and proboscis being in a straight line.

The eggs are laid singly and are provided with a partial envelope that

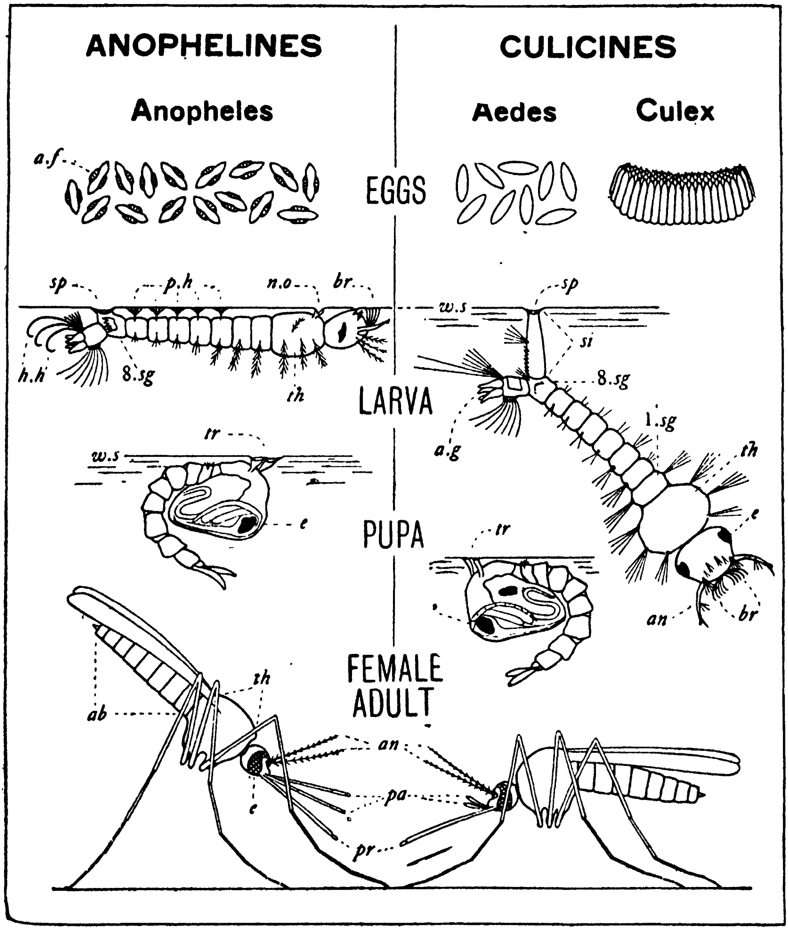

Fig. 21. Distinguishing features of anophilines and culicines; *a.f.*, air floats; *a.g.*, anal gills; *ab.*, abdomen; *an.*, antenna; *br.*, mouth brush; *e.*, eye; *hh.*, grapnel hairs; *n.o.*, notched organ; *pa.*, maxillary palp; *p.h.*, palmate hairs; *pr.*, proboscis; 1.*sg.*, 1st abdominal segment; 8.*sg.*, 8th abdominal segment; *si.*, siphon; *sp.*, spiracles; *th.*, thorax; *tr.*, respiratory trumpets; *w.s.*, water surface.

(*After Marshall and Smart.*)

acts as a float. The larvae do not possess a breathing siphon and feed and take their air lying flat on the surface of the water. The pupae have very short breathing trumpets and do not as a rule hang straight down from the surface of the water (Fig. 21).

Tribe Culicini

The palpi of female culicines are much shorter than the proboscis. When the adults rest or feed, the body is more or less parallel to the surface, the proboscis being directed downwards and not in line with the body (Fig. 21).

Eggs may be laid singly or in masses to form "rafts". The rafts float, but the single eggs are not provided with floats as in anophelines. The larva usually has a long breathing trumpet, and when taking air from the water surface hangs from it at an angle. The pupae are provided with breathing trumpets of varying lengths and frequently hang straight down from the surface (Fig. 21).

Mosquitoes are well-known blood-sucking pests throughout the world, and are notorious as vectors of serious diseases among both man and livestock (p. 100).

Sub-order BRACHYCERA

Family TABANIDAE (March-flies, Horse-flies, Gad-flies)

Medium to stout flies without bristles (Fig. 72); head broad and flattened transversely, with large eyes; antennae three-segmented, the

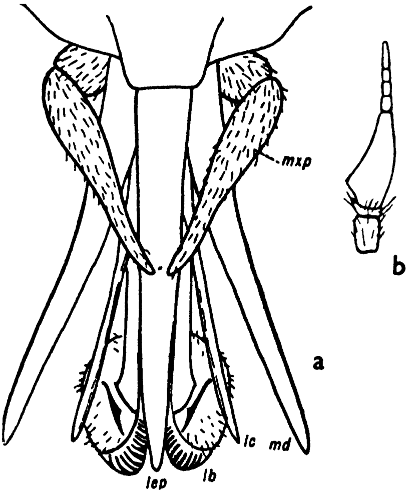

Fig. 22. (*a*) Mouth-parts of tabanid fly; *lb.*, labella; *lc.*, maxilla; *lep.*, labrum-epipharynx; *md.*, mandible; *mxp.*, maxillary palp; (*b*) antenna of tabanid fly. (*After Tillyard.*)

third segment with four to eight annulations (Fig. 22 (*b*)); proboscis erect, constructed for piercing but ending in a pair of fleshy labella (Fig. 22 (*a*)); venation normal (Fig. 5 (*b*)); tarsi ending in a pair of claws, below which are a pad-like empodium and a pair of pulvilli; larvae cylindrical, aquatic and carnivorous, the abdomen with rings of pseudopod-like processes (Fig. 69 (*b*)).

A large number of tabanids live on blood. Their bite is particularly severe, and the flies are associated with the carriage of many diseases, most of which are spread in a mechanical manner (p. 106).

Sub-order CYCLORRHAPHA

Section **Schizophora**

Family MUSCIDAE

Moderate-sized grey and black flies with a sucking or piercing proboscis (Figs 23 (*b*), 24 (*b*)); antennae with usually a large third segment and an arista plumose almost to the tip (Fig. 23 (*c*)); hypopleural bristles absent; abdomen without dorsal and apical bristles; vein M_1 curved or sharply bent towards vein R_{4+5} (Figs 23 (*a*), 24 (*a*)).

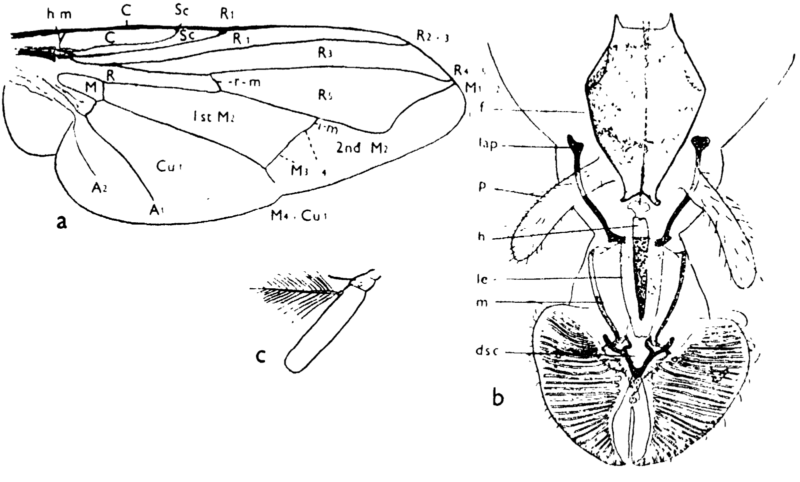

Fig. 23. (*a*) Wing of *Musca domestica;* (*b*) mouth-parts of *M. domestica* (dorsal view); *d.sc.*, discal sclerite; *f.*, fulcrum; *h.*, hypopharynx; *l.ap.*, labial apodeme; *l.e.*, labrum-epipharynx; *m.*, mentum; *p.*, palp; (*c*) antenna of muscid fly.

(*Fig.* (*a*) *after Patton and Evans; Fig.* (*b*) *after Monnig; Fig.* (*c*) *after Tillyard.*)

KEY TO MUSCIDAE AFFECTING LIVESTOCK IN AUSTRALIA

1. Proboscis rigid and projecting; blood-sucking flies.............................. 2
   Proboscis soft and retractible.. 3
2. Small brownish-grey species; palpi as long as proboscis; abdomen with an inconspicuous median longitudinal stripe.................................
   .... *Siphona exigua* (p. 117 and Fig. 78)

Larger black and grey species; palpi about half as long as proboscis; thorax with four dark stripes; abdomen with dark spots and bands...... ....*Stomoxys calcitrans* (p. 115 and Fig. 77)

3. Thorax with four well-defined black stripes; a bunch of hairs in front of the anterior thoracic spiracle and below the humeral callus............ ....*Musca domestica* (p. 108 and Fig. 75 (*a*), (*c*))

Thorax with the outer two stripes on each side fused, so that only two broad stripes are visible; no such bunch of hairs............................ ....*Musca vetustissima* (p. 112 and Fig. 75 (*b*), (*d*))

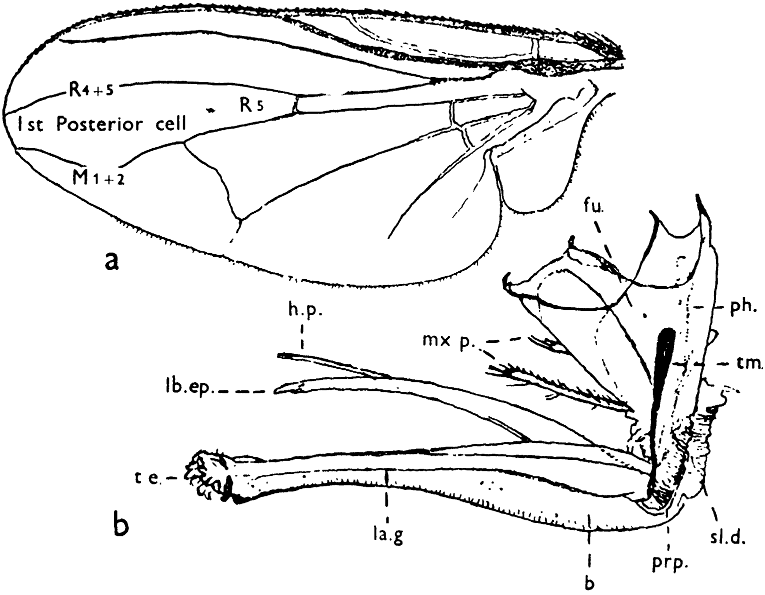

Fig. 24. (*a*) Wing of *Stomoxys calcitrans*; (*b*) mouth-parts of *S. calcitrans* (lateral view); (*b*), bulb; *fu.*, fulcrum; *hp.*, hypopharynx; *la.g.*, labial gutter; *lb.ep.*, labrum-epipharynx; *mx.p.*, maxillary palp; *ph.*, pharynx; *prp.*, prepharynx; *sl.d.*, salivary duct; *te.*, teeth; *tm.*, torma.

(*Fig.* (*a*) *after Patton and Evans; Fig.* (*b*) *after Patton.*

In Australia the only blood-sucking flies larger than the mosquitoes, sandflies, and black-flies are the tabanids, the stable fly and buffalo fly. There should therefore be no difficulty in recognizing these flies. Several species of *Siphona* attack stock in various parts of the world, the most important being the horn-flies of North America, *S. irritans*, and of Africa, *S. minima*, and the buffalo fly, *S. exigua*, of Australia and Asia. Other species of *Stomoxys* are also known; *S. nigra*, for example, is widely distributed in Africa. Several species of the genus *Musca* in Australia are associated with livestock, and from these *M. domestica* and *M. vetustissima* can be readily distinguished by the characters given in the above key. One interesting species of this genus is *M. crassirostris*, which is found in India and Africa. This fly feeds on blood, obtained by rasping the skin with its strongly developed prestomal teeth, situated on a soft and retractile proboscis.

The tsetse flies, *Glossina* spp., are also members of the family Muscidae. They are confined to Africa (p. 124).

Family CALLIPHORIDAE (Blowflies, Screw-worm Flies—Frontispiece and Fig. 84)

Metallic blue, green or brownish flies, with characters similar to those of the Muscidae, but from which they may be distinguished by the presence of hypopleural bristles.

Many species of this family lay their eggs on living flesh. Almost any animal, including man and sometimes birds, may be attacked. Losses are most serious among sheep and cattle. Some flies, the so-called screw-worms, are obligatory in this type of parasitism, but other species also breed in carrion (p. 126).

Family OESTRIDAE (Bot-flies and Warble Flies)

Stoutly built, more or less pilose flies, some species bee-like in appearance; antennae short and partially sunken in facial grooves; mouthparts rudimentary, no visible proboscis; adults free-living, larvae parasitic in mammals.

This family includes the horse bot-flies, *Gastrophilus* spp. (p. 143 and Fig.

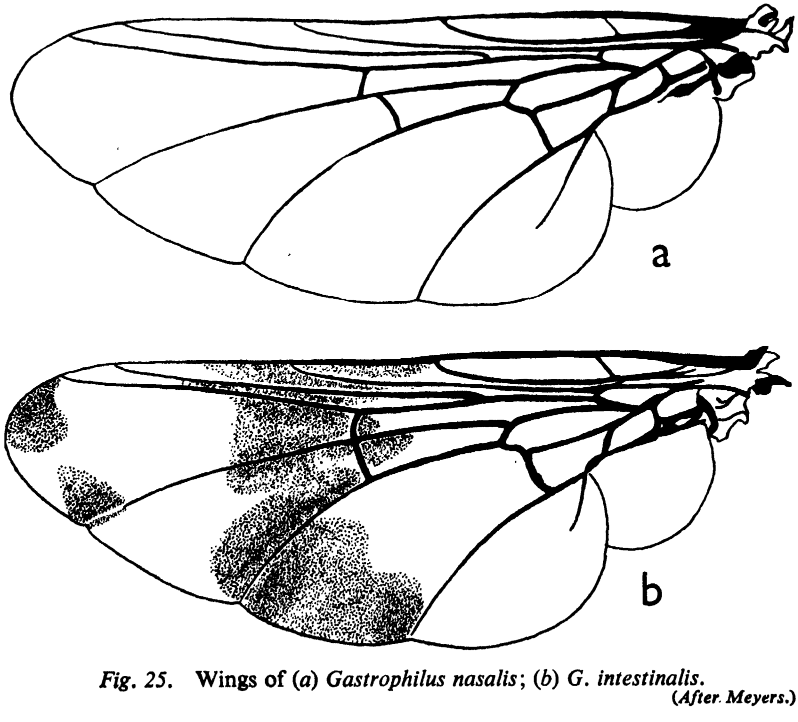

Fig. 25. Wings of (*a*) *Gastrophilus nasalis*; (*b*) *G. intestinalis.*
(*After Meyers.*)

90), the cattle warble flies, *Hypoderma* spp. (p. 147 and Fig. 93), the tropical warble fly, *Dermatobia hominis* (Linn.), the camel bot-fly, *Cephalopsis tittilator* Clark, the sheep nasal-fly, *Oestrus ovis* (Linn.) (p. 149 and Fig. 94) and the horse nasal-bot, *Rhinoestrus purpureus* Bauer.

The species of *Gastrophilus* and *O. ovis* are world-wide in distribution. *Hypoderma* spp. are confined to the northern hemisphere, mainly Europe and North America, though larvae are sometimes seen in cattle imported from these regions into Australia and South Africa. The tropical warble fly, *D. hominis,* is limited to the tropical and subtropical regions of America, where its larvae are found beneath the skin of all domestic animals and man. It is a particularly serious pest of cattle. The female fly lays her eggs on species of mosquitoes (mainly *Psorophora* sp.), and on other biting flies and also ticks. When these come into contact with a warm-blooded animal the eggs hatch and the larvae penetrate the skin. The larvae of *C. tittilator*, which is present in Australia, occur in the pharynx of camels, being deposited in the nostrils; whilst the larvae of *R. purpureus* infest the nasal cavities and sometimes the pharynx of horses in central and southern Europe, Russia, and Algiers.

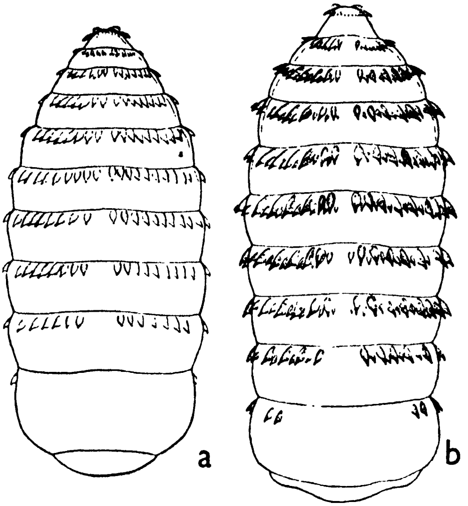

Fig. 26. Fully grown horse bot-fly larvae. (*a*) *Gastrophilus nasalis*; (*b*) *G. intestinalis;* (*c*) *G. haemorrhoidalis.*

(*After Wells and Knipling.*)

KEY TO THE AUSTRALIAN SPECIES OF GASTROPHILUS

Adults

1. Wings smoky with a brown band and apical spots..*G. intestinalis* (p. 144 and Fig. 25(*b*))
   Wings clear.. 2
2. Cell M (anterior basal cell) equal in length or almost so to cell 1st M_2 (discal cell)...............................*G. nasalis* (p. 144 and Fig. 25 (*a*))
   Cell M much shorter than cell 1st M_2; abdomen with a bright orange tip ....*G. haemorrhoidalis* (p. 144)

Larvae

1. Each segment with only one row of spines.........*G. nasalis* (Fig. 26 (*a*))
   Two rows of spines present.. 2
2. Spines blunt at tip; only one to two pairs of spines lacking on dorsal centre of segment 10..*G. intestinalis* (Fig. 26(*b*))
   Spines tapering to a fine point; band of spines on dorsum of segment 10 interrupted by at least half the width of the segment............................
   .... *G. haemorrhoidalis* (Fig. 26 (*c*))

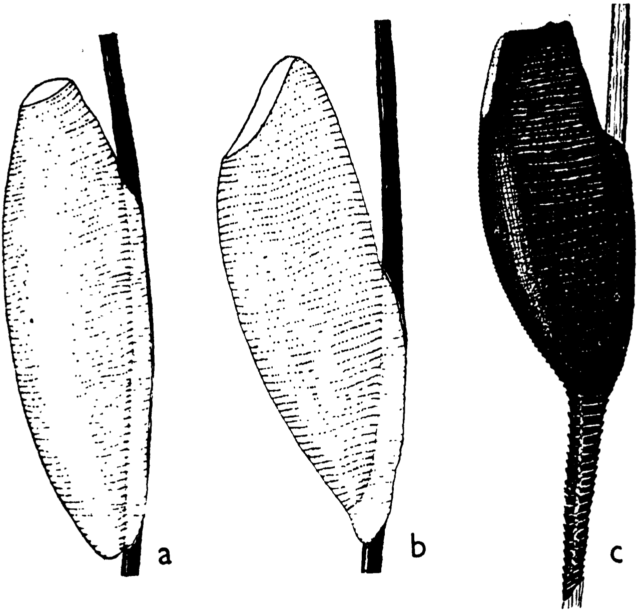

Fig. 27. Eggs of (*a*) *Gastrophilus nasalis*; (*b*) *G. intestinalis*; (*c*) *G. haemorrhoidalis*.
(*After Wells and Knipling.*)

Section **Pupipara**

Family HIPPOBOSCIDAE

Blood-sucking flies, ectoparasitic on warm-blooded vertebrates; head and thorax compressed dorso-ventrally and often furnished with spines and ctenidia; abdomen not or indistinctly segmented, sac-like; palpi flattened and ensheathing proboscis; wings present or absent, the veins mostly crowded anteriorly; legs strong, claws of the tarsi toothed; larva retained within body of female until fully grown.

KEY TO HIPPOBOSCIDAE AFFECTING LIVESTOCK IN AUSTRALIA

1. Wings absent...........................*Melophagus ovinus* (p. 152 and Fig. 96))
   Wings present... 2
2. Claws bidentate; wings rilled as in Fig. 28 (*b*)...*Hippobosca equina* (p. 154)
   Claws tridentate; wings flat, normal; only one cross-vein...............................
   ....*Pseudolynchia canariensis* (p. 155 and Fig. 28 (*a*))

Species of *Hippobosca* occurring in other parts of the world include *H. maculata* Leach on cattle and horses in Africa, Europe, and Asia, *H. rufipes* Van Olfers on cattle and horses in southern Africa, and *H. camelina* Savigney on camels. The latter is also recorded from Australia.

Hippoboscids are not uncommon on kangaroos and wallabies, and the species that have been described belong to the genus *Ortholfersia*, whilst species of *Ornithomyia* and *Lynchia* occur on Australian native birds.

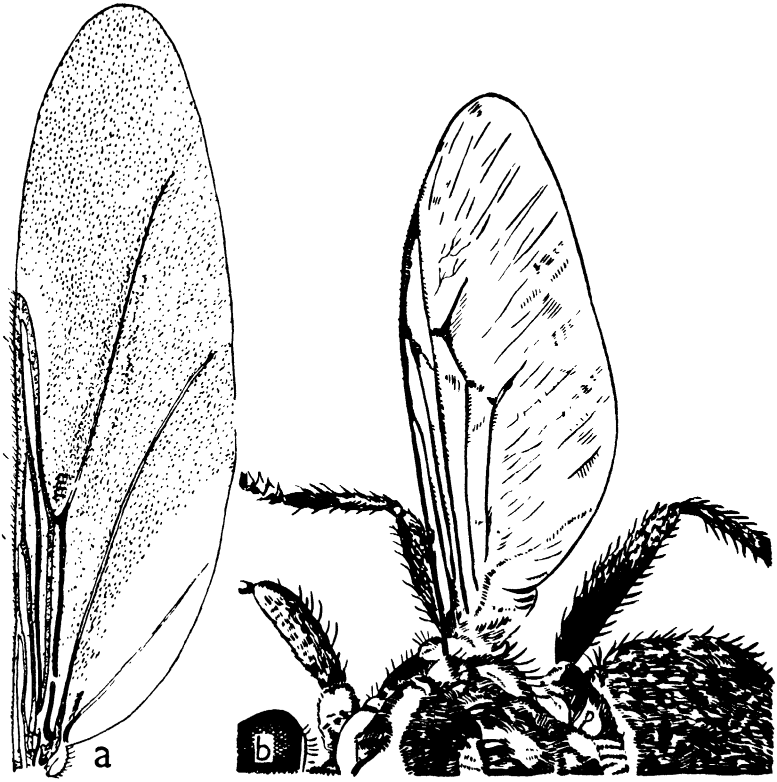

Fig. 28. Wings of (*a*) *Pseudolynchia canariensis;* (*b*) *Hippobosca maculata.* In the genus *Hippobosca* the wings are rilled after the manner of a partially opened fan. (*Fig.* (*a*) *after Bedford.*)

The families Nycteribidae and Streblidae contain those species of louse-flies that infest bats.

IMPORTANT SPECIES OF INSECTS

Cockroaches. Of the 300 species of cockroaches recorded from Australia, only *Leucophoea surinamensis* (Fig. 29) is of known veterinary importance. This species, which occurs in many tropical areas throughout the world, is the intermediate host of *Oxyspirura mansoni*, the poultry eye-worm, which is found in tropical Australia. *L. surinamensis* is a semi-domesticated cockroach occurring in poultry-houses, stables, etc. It is about 20 millimetres long. The head and thorax are dark, with yellow markings, and the forewings are grey-brown, each with a pale stripe along its anterior margin.

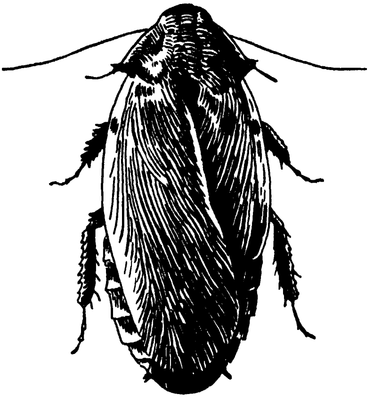

Fig. 29. Leucophoea surinamensis, the intermediate host of the poultry eye-worm, *Oxyspirura mansoni* (dorsal view). (*After Sanders.*)

Cockroaches are nocturnal, and feed on a wide variety of substances, including excreta and foodstuffs, and are thus capable of carrying disease organisms, such as species of *Salmonella. Blatella germanica* (Linn.) (Fig. 30 (*a*)) is an intermediate host of *Gongylonema ingluvicola*, a poultry roundworm, and also of *G. pulchrum*, a roundworm infesting ruminants, equines, the pig, and man. Two other domestic species, *Periplaneta americana* (Linn.) (Fig. 30 (*c*)), and *P. australasiae* (Fabr.) (Fig. 30 (*b*)) are intermediate hosts of another poultry roundworm, *Tetrameres fissipinus*. Of these parasites, only *G. pulchrum* is recorded from Australia.

Control. In poultry-houses cockroaches may be controlled by removing all litter and spraying with 5 per cent DDT or 2 per cent chlordane. A concentration of 0·5 per cent gamma BHC is also satisfactory.

Grasshoppers. Several species of grasshoppers are intermediate hosts of the tapeworms *Choanotaenia infundibulum* of fowls and *Metroliasthes lucida* of turkeys, and of the chicken gizzard worm, *Acuaria hamulosa*, in the United States and Hawaii. These three worms occur in Australian poultry, but the insect intermediate hosts in this country are unknown.

Beetles. Many species of coprophagous beetles are intermediate hosts of parasitic worms (Fig. 8). No particular species has yet been incriminated in Australia, but worm parasites recorded from Australian pigs, and carried by beetles in other parts of the world, include—*Physocephalus sexalatus*, *Ascarops strongylina*, and *Macracanthorhynchus hirudinaceus*. Species recorded from Australian poultry and carried by beetles in other parts of the world include *Raillietina cesticillus*, *Choanotaenia infundibulum*, *Hymenolepis carioça*, and *Acuaria hamulosa*.

Spirocerca lupi of the dog and *Subulula brumpti* of chickens are two roundworm parasites also carried by beetles, but not present in Australia.

Because of their habit of feeding on carcasses, scavenger beetles have been known to spread diseases such as anthrax. Some beetles are poisonous if eaten by stock; for example, in the United States the rose-chafer, *Macrodactylus subspinosus*, is toxic to chickens, and in southern Europe the Spanish fly, *Lytta vesicatoria*, causes fatalities among cattle and sheep.

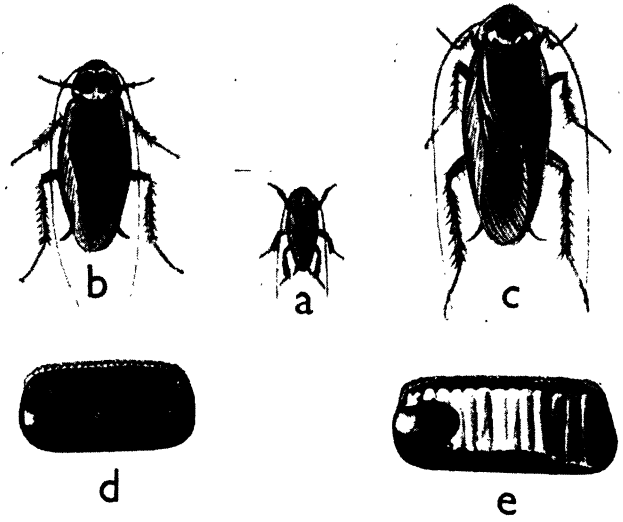

Fig. 30. Common cockroaches. (*a*) *Blatella germanica;* (*b*) *Periplaneta australasiae;* (*c*) *P. americana;* (*d*) ootheca; (*e*) ootheca opened to show eggs.
(*After Helmsing.*)

A few beetles, particularly species of *Onthophagus*, have been recorded as leading a pseudo-parasitic existence in the digestive tract of man and the horse. Beetle larvae have been found in the eye, nose, and urogenital tract of man.

Bees and Wasps. These insects have a severe sting. Their association with livestock is purely accidental, but they may occasion serious injuries by causing an animal to panic and to run away. Bee stings have been known to be fatal to poultry and horses.

Ants. Mortalities among poultry from ingestion of ants have been recorded in Queensland, Western Australia and New South Wales. *Monomorium rothsteini* and *M. bicorne* have been associated with serious losses on the Darling Downs in Queensland, and in Western Australia, respectively.

The winged forms are eaten during swarming after rain. Species of *Chremastogaster*, *Chalcoponera*, and *Iridomyrmex* have also been incriminated.

Ants of the genera *Pheidole* and *Tetramorium* are recorded in the United States as intermediate hosts of two poultry tapeworms, *Raillietina tetragona* and *R. echinobothrida*, both of which are well known in Australia.

The Cattle-Poisoning Sawfly (*Platypsectra interrupta* (**Klug**)). Serious fatalities among cattle through the ingestion of the larvae of this insect have been reported on numerous occasions since 1911 from the Maranoa and adjoining districts of Queensland.

Habits and Life History. The adult sawfly is a glossy, blue and yellow insect with smoky wings (Fig. 31 (*d*)), and is seen on the wing during the late summer. It lays its eggs in the leaves of the silver-leaf ironbark, *Eucalyptus melanophloia*, and sometimes also of the narrow-leaf ironbark, *E. creba*, the grey gum, *E. penicillata*, and more rarely of other trees, such as apple, *Angophora intermedia*. The eggs (Fig. 31 (*a*)) hatch in about three weeks, and the larvae, which feed on the leaves, are fully grown four to five months later. The larvae are pale green to yellowish in colour, with reddish-yellow heads and numerous white spots scattered over the body (Fig. 31 (*b*)). The body of the larvae gradually tapers to a blunt point surmounted by a long black spike. When fully grown the larvae descend the tree and burrow into the ground, forming earthen cocoons, in which they pupate (Fig. 31 (*c*)). The pupal period lasts about six months.

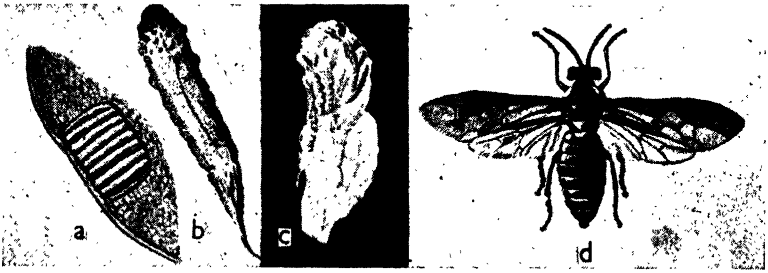

Fig. 31. The cattle-poisoning sawfly, *Platypsectra interrupta.* (*a*) Row of eggs within tissue of leaf; (*b*) sawfly larva; (*c*) pupa, extracted from earthen cocoon in soil; (*d*) female sawfly.

(*After Helmsing.*)

Association with cattle. Although the insect and its main food-trees are widely scattered throughout Australia, it is associated with fatalities among cattle only in the Maranoa and adjoining districts of Queensland. In certain years in these districts the larval population is so high that the food-trees over extensive areas are stripped of their leaves, and the larvae die of starvation in large heaps at the foot of the trees. For some reason, at present unknown, cattle avidly eat these heaps, fighting one another in their greed. Mortalities may be severe, death being due to some toxic substance in the larvae, for sheep can be readily killed when fed either live larvae or larvae from the rotting heaps. This toxic substance can remain active over a long period, for cattle will die after eating from a heap of dead larvae so old as to be reduced almost to a dry powder.

Control. The destruction of the main food-trees by ringbarking has been recommended as a control measure. However, this has been claimed to be uneconomic. An alternative would be to ringbark the trees in only one or two paddocks, to which the cattle could be moved during critical periods. It has been said that the main factor controlling the sawfly population in the years prior to these outbreaks was the possum, which consumes large numbers of sawfly eggs and larvae with the leaves on which it feeds. It was thought that outbreaks of sawfly poisoning were due to the extermination of these animals. The affected area has now been a sanctuary for the possum for many years.

It seems possible that the ingestion of the larvae by cattle is due to some deficiency in their diet, and that losses could be prevented by feeding the element or elements in question to the animals. There has not been much work done in this respect, but it would seem that neither phosphorus nor calcium are incriminated.

Moths and Butterflies. In Australia, stomatitis and deaths among sheep have followed the ingestion of the larvae of the procession caterpillar, *Ochrogaster contraria* (Walk.). These larvae are provided with long hair-like spines. They live in communities in bag shelters in trees and may be accidentally eaten by animals with foliage on which the larvae are feeding. This species is a representative of a large number of "hairy" caterpillars, the hairs, on contact with the skin, piercing it and then breaking off and causing severe irritation. Larvae of the butterfly *Anapheis java teutonia* (Fabr.) have been suspected in Queensland of causing deaths among pigs which have eaten them. In other parts of the world, larvae of the cabbage butterfly, *Pieris brassicae*, if eaten by stock, may cause stomatitis, colic, and death. In South Africa, the pupae of the moth *Nudaurelia cytherea* are fatal to pigs.

The Bed-Bug (*Cimex lectularius* **Merritt**). This is a broad, flat, dark-brown insect, between 6 and 10 mm. long, with a strong, characteristic odour. The wings are represented by a pair of small, shiny pads and the body is covered with small bristles set in pits (Fig. 32). The bed-bug is cosmopolitan in its distribution.

Habits and Life History. Bed-bugs are normally active only at night, and during the day they hide away in cracks and crevices. They live on blood, and when undisturbed are fully fed in from three to five minutes. The mature female may live up to ten months under favourable conditions, and on the average lays 200 eggs. These are laid in the cracks and crevices in which the insects hide. The egg is pearly-white and oval and not quite 1 mm. long. In warm weather hatching occurs in six to seventeen days. The young bug is small and pale, and it moults five times before reaching the adult stage, at least one meal of blood being required between each moult. In warm weather the adult stage is reached four to six weeks after hatching. This period may be considerably lengthened under conditions of starvation or low temperatures. Unfed adult bugs may live as long as two months.

Importance. Primarily a parasite of man, the bed-bug may also attack poultry, and on account of its blood-sucking activities large populations may cause loss of condition and decreased egg production. Young birds are the most susceptible. Heavy infestations are sometimes encountered in pigeon-lofts, and losses among the squabs may be serious. The insect is said to be capable of transmitting fowl-pox.

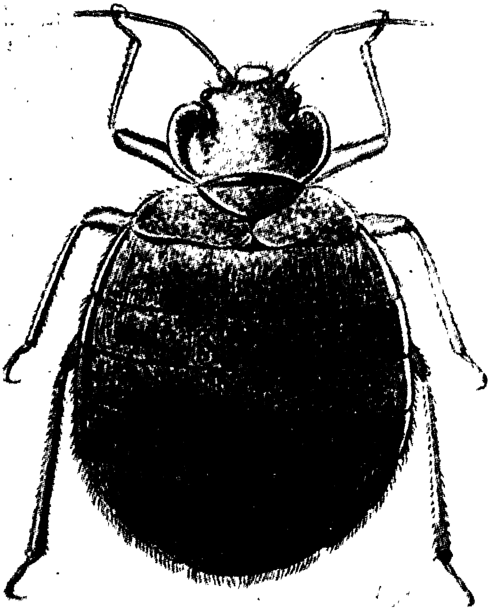

Fig. 32. The bed-bug, *Cimex lectularius* (dorsal view).
(*After Helmsing.*)

Its status as a vector of diseases affecting man is obscure, and, although it can be experimentally infected with the organisms of such diseases as tularaemia, relapsing fever, and murine typhus, the extent to which it may be a natural vector is unknown.

Control. The first step towards control is thorough cleansing of the affected poultry-houses or pigeon-lofts, and the burning of all litter, including nesting straw. The premises are then sprayed with 5 per cent DDT, including the perches, walls, and roofs. The DDT is best prepared as a kerosene solution, though emulsions are also very effective. One treatment will effect eradication. BHC (0·1 per cent gamma), and chlordane (2 per cent) are equally effective.

Both DDT and BHC have the disadvantage that they may be carried by the birds into the nest boxes and may taint the eggs for a week or two after treatment. Whether chlordane has a similar result is not known. To avoid the possibility of egg taint, it may be best to use kerosene, creosote, or crude oil. None of these has any residual action, and several treatments are necessary to bring about control. They must be forced under pressure into all cracks and crevices in which the bugs may be sheltering.

Fleas

Habits and Life History. All fleas live on blood. Under conditions of favourable temperatures and humidity and frequent blood meals, the adult may live for many months. Having once fed, fleas must continue to feed, for otherwise their life is comparatively short. Newly emerged and unfed fleas can live for many weeks, and these are the ones that occur in houses that have not been occupied for a time. Whilst there are certain hosts to which a species may be best adapted, many fleas, if hungry, will attempt to feed on any warm-blooded animal with which they come into contact.

The female flea usually lays her eggs in the host's nest or bedding or in the fur or feathers of the host. If laid on the host they eventually drop to the ground. They are small, oval, and whitish (Fig. 33 (*d*)). The length of the incubation period depends on the species and on the prevailing temperatures and humidities, and under optimum conditions is about

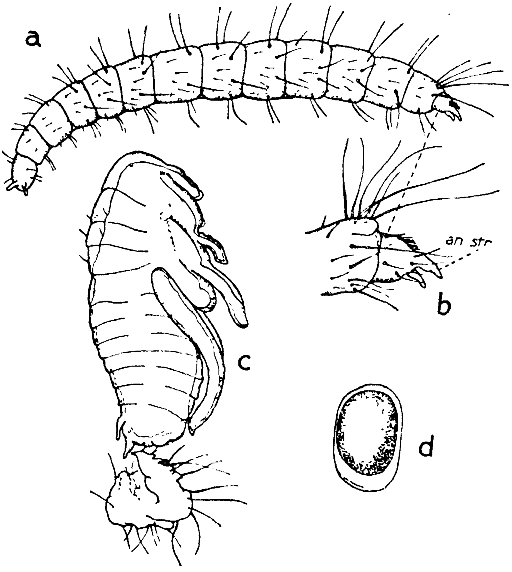

Fig. 33. The life cycle of a flea, *Xenopsylla cheopis.* (*a*) Fully grown larva; (*b*) end of abdomen of larva showing anal struts (*an. str.*); (c) pupa with cocoon removed; (*d*) egg.

(*After Patton and Evans.*)

two days. The larva (Fig. 33 (*a*)) is a cylindrical maggot-like creature with a whitish body and a small brownish head. There are neither eyes nor legs. It moves very actively in the dust and debris in which it lives, avoiding light and feeding on organic matter, such as the dried blood passed in the faeces of the adults. It thrives on a dry blood diet, and some species will not develop in the absence of this food material. With favourable temperatures and an abundance of food, the larva is fully grown in one to two weeks when it measures about 6 mm. in length. It then spins a cocoon, to which particles of debris adhere (Fig. 33 (*c*)). The adult emerges one to three weeks later, if conditions are favourable.

Fleas Infesting Domestic Animals

Dog and Cat Fleas (*Ctenocephalides canis*—Fig. 34 (*b*)—and *C. felis*—Fig. 34 (*a*)). These are the common fleas of dogs and cats, both species being world-wide in their distribution. Although designated as the dog flea and the cat flea, each species is not restricted to the one host. Indeed, in the warmer regions of Australia *C. felis* is much more common on dogs and cats than *C. canis*, whilst *C. canis* is more prevalent in the more temperate areas. Cattle—particularly calves—horses, pigs, poultry, and man, are also readily attacked. Both species of fleas are encountered in outbreaks in dwellings, stores, and stables.

The Human Flea (*Pulex irritans*—Fig. 34 (*c*), (*d*)). This is also a widely distributed parasite, attacking all classes of domestic animals, also poultry and man. It is rarely seen in large numbers on dogs and cats, but serious outbreaks are not infrequent among pigs and poultry. The flea encountered in dwellings in sandy areas, particularly at the seaside, is usually *P. irritans.*

Stickfast Fleas. The most important of these is *Echidnophaga gallinacea* (Figs 34 (*e*), 35), the poultry stickfast flea, which may attack all kinds of domestic and many wild animals and birds. It is dealt with in detail on p. 63. Two other species, *E. myrmecobii* and *E. perilis*, are parasites of native animals, but are not uncommon on dogs and cats in the inland areas of Australia. Both species are also found on the wild rabbit, heavy infestations of *E. myrmecobii*, the "red flea", in particular, being frequently seen. Both are easily mistaken for *E. gallinacea.*

"Stickfast" or "sticktight" fleas differ from other fleas not only in the greatly reduced thorax, but also in their tick-like habit of remaining attached to their host and not moving over the body. The human chigoe or jigger flea, *Tunga penetrans*, of tropical America and Africa is another well-known species of this family.

Stickfast fleas on dogs and cats occur in colonies in the ears, round the eyes, nose, and throat, between the paws, on bare parts of the abdomen, and on the scrotum and perineum.

Importance. Because of their blood-sucking habits and severe bite, fleas are extremely irritating parasites, and the rapidity with which infestations increase—particularly on animals unable to care for themselves because of ill-health and for other reasons—sometimes leads to serious consequences. Heavy infestations can be fatal to puppies and kittens. Some dogs are extremely susceptible to moderate or even light

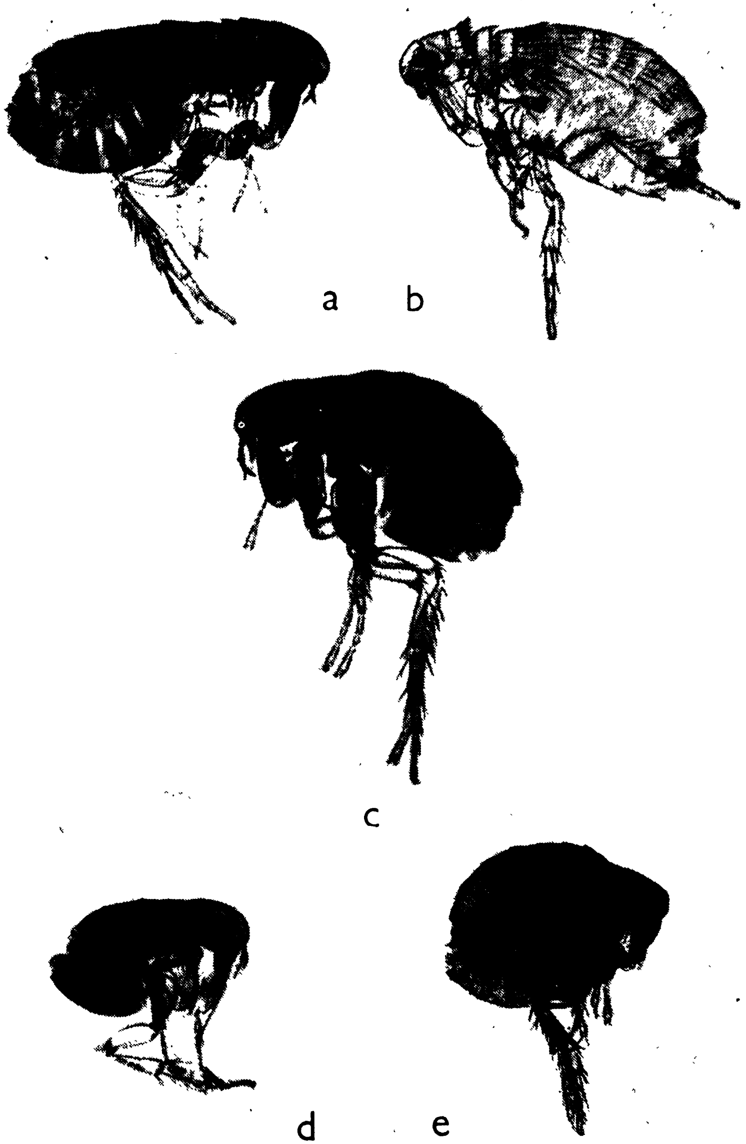

Fig. 34. Common fleas infesting livestock. (*a*) *Ctenocephalides felis*, female; *b*) *C. canis*, female; (*c*) *Pulex irritans*, female; (*d*) *P. irritans*, male; (*e*) *Echidnophaga gallinacea*, female.

(*After Keith*.

infestations, which may cause a condition of dermatitis known as summer eczema.

C. canis, *C. felis*, and *P. irritans* are intermediate hosts of the common dog and cat tapeworm, *Dipylidium caninum*, which is occasionally also found in children. There is some evidence that *Dirofilaria immitis*, a serious heart-worm parasite of dogs, may be carried by these fleas as well as by certain species of mosquitoes. *E. myrmecobii* is a vector of myxomatosis among rabbits.

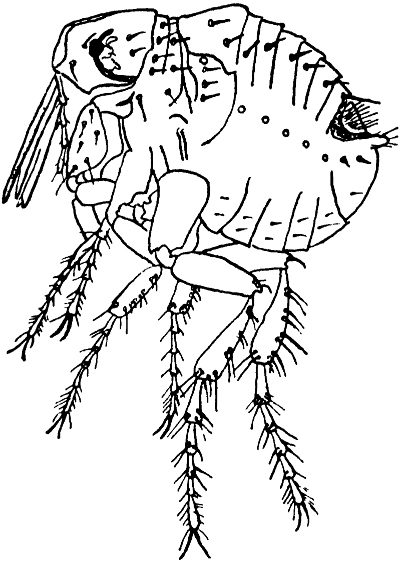

Fig. 35. The poultry stickfast flea, *Echidnophaga gallinacea* (lateral view).
(*After Patton and Cragg.*)

Haemorrhagic septicaemia of cattle (*Pasteurella boviseptica*), and possibly brucellosis, may be carried by *C. felis*. The former disease occurs in Australia, but does not attain the serious proportions recorded in other countries, whilst brucellosis is common.

Control. Several effective insecticides are available for the control of fleas on domestic animals. The breeding places of the parasites must also receive attention.

Pyrethrum and derris dusts (10 per cent) have been in use for many years, the powder being dusted into the coat and allowed to act for 20 to 30 minutes. The coat is then brushed and the dead and stupified fleas caught on paper and burnt. Derris may also be used as an aqueous suspension in soapy water, 1 oz. of derris per gallon of wash. These insecticides give little protection against reinfestation.

DDT may be applied as a powder, 5 to 10 per cent DDT in pyrophillite, or better still as a wash, when concentrations of 0·5 to 1 per cent

DDT will kill all fleas and keep the animal clean for periods of two to three weeks. It is best to use suspensions, since the solvent present in many emulsions may irritate the skin. DDT may also be incorporated in a soap. This insecticide can be safely used in the case of dogs, calves, and pigs, but it is toxic to cats.

BHC at concentrations of 0·5 per cent as a dust, or 0·01 per cent gamma isomer as a wash, is also very effective, but may be dangerous on cats. Chlordane at 0·25 per cent concentration is another effective insecticide.

Kennels should be kept clean and any bedding boiled weekly. All litter must be swept up and burnt. DDT is highly efficient against the larvae, and a 5 per cent concentration sprayed or dusted over the area in which breeding is occurring will give excellent control. In infested houses and stores the DDT is applied to the floors, rugs, etc. Since these outbreaks originate from infested dogs and cats, these animals must receive attention as well.

Breeding may also be controlled in yards, and beneath houses and other similar dry, dusty places, by keeping the areas damp. Where there is no danger to livestock it is advantageous to scatter salt before dampening.

Fleas Infesting Poultry

The Chicken Flea (*Ceratophillus gallinae* **Schrk.**). This species is a common pest of chickens in parts of Europe. It is also recorded from the United States, New Zealand, and Australia (New South Wales).

The Poultry Stickfast Flea (*Echidnophaga gallinacea* **Westw.**—Figs 34 (*e*), 35). This is a small, delicate species that primarily attacks poultry, but it will also infest wild birds, such as the magpie (*Gymnorhina tibicen*), the flock pigeon (*Ocyphaps lophotes*), the grey-crowned babbler (*Pomatostomus temporalis*), and the soldier bird (*Myzantha melanocephala*). In addition it attacks the dingo, the kangaroo, the rabbit, the rat, cattle, the goat, the dog, the cat, the horse, and man. Its distribution is worldwide, for it is recorded from Europe, Asia, Africa, the United States, Mexico, the Hawaiian Islands, and Australia. In Australia *E. gallinacea* is found in every State except Tasmania. Both Queensland and New South Wales have only recently been infested, the flea being confined to the Boonah district of Queensland, and the Broken Hill, Wentworth, Narrandera, and Murrumbidgee Irrigation areas in New South Wales. In Victoria it is present in the Mildura district, and it is widespread in South and Western Australia, being most common on sandy soils and in drier areas.

Habits and Life History. Poultry are usually attacked on the comb, wattles, back of the head, and round the eyes and beak (Fig. 36). Sometimes fleas are seen under the wings, on the breast, and around the vent, though these parts of the body are usually attacked only when the birds are moulting.

As with other species of stickfast fleas, these parasites bury their mouth-parts in the flesh and remain fixed in position, appearing as dense, shiny, black masses. The males live about two to six days after mating and the females up to about six weeks on the host. In the absence of a host the females survive for only short periods. Oviposition commences six to ten days after attachment, the eggs being "shot out" by the females before falling to the ground. Egg-laying takes place chiefly at night, each female depositing about twelve eggs every 24 hours. The eggs are oval and pearly-white and measure 0·3 mm by 0·26 mm. Under favourable conditions hatching occurs in six to eight days. The newly hatched larva is white in colour, less than 1 mm in length, and has a ring of fine hairs on the posterior margin of all segments except the last. The surface of the body is covered with minute warty protuberances. It moves actively among the debris in which it lives and when disturbed, quickly buries itself. Under favourable conditions it is fully grown in fourteen to thirty-one days, when it is a little more than 3 mm in length. The fully grown larva burrows into the debris and forms a cocoon in which it pupates, the adult emerging nine to nineteen days later. The fleas do not attach for five to eight days after emergence.

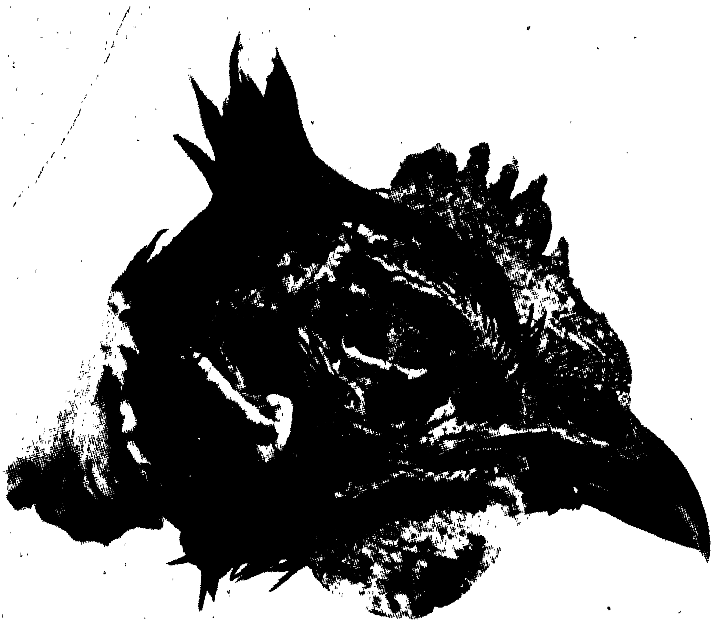

Fig. 36. Head of hen heavily infested by *Echidnophaga gallinacea*.
(*After Newton.*)

The optimum temperature for development is 80° F. and the optimum humidity about 80 per cent. The fleas thrive best in summer, but the immature stages are capable of surviving severe winter temperatures.

Importance. These fleas are most serious among young birds, and a heavy infestation causes the birds to become dull and droopy and even to die. In older birds it is claimed that prolonged exposure to infestation may result in loss of condition through the development of anaemia, and in decreased egg-production. Occasionally the birds injure their eyes by scratching in the attempts to relieve the irritation.

Control. Excellent control may be secured by dipping the birds in a suspension of DDT containing 0·5 to 2 per cent of the insecticide. This treatment kills all fleas and gives good control at the lowest concentration, and if properly carried out at the highest concentration will ensure two to five months' freedom from reinfestation. Eradication will be hastened if the poultry-house floors are sprayed or dusted with DDT.

DDT at concentrations of 5 to 10 per cent dusted over the infested areas on the birds will kill the fleas, but this is not nearly as effective against reinfestation as a wash. Emulsions should not be used, for the solvents are too irritant.

BHC suspensions and dusts applied to the head and neck at concentrations of 0·05 per cent and 0·5 per cent gamma isomer respectively, are also effective, but give less residual protection than DDT.

Both the DDT and the BHC insecticides may taint the eggs and the carcass, a serious disadvantage where commercial poultry farms are concerned. DDT dipping has also been associated with mortalities among fowls and ducks, possibly as a result of a diet deficient in calcium. Where eradication is the principal consideration, the use of DDT as a dip is justified. Otherwise, it appears safest to use oily substances such as carbolated petroleum, castor oil, neatsfoot oil, or red oil emulsion (1 : 3). When applied to the infested areas these kill the fleas, but give little residual protection.

Breeding can be controlled by the frequent removal and destruction of all litter, and spraying with kerosene to kill unattached fleas. Keeping the litter damp or applying liberal amounts of sulphur are other methods of preventing breeding. It has also been suggested that large iron trays be suspended beneath the roosts to catch the eggs, which can then be destroyed with strong disinfectant.

Lice

Lice are permanently parasitic, and if removed from their host they usually die within a few days. They spread from host to host chiefly by contact. Their host specificity is usually very high, and as a rule a species of louse is found only on one species of host, or at most on a group of closely related hosts. Indeed it has been claimed that much information concerning the phylogenetic relationships of animals and birds can be obtained by a study of their lice. The most notable exception to this is *Heterodoxus longitarsus* (Paiget), a louse normally found on the kangaroo, and which in many parts of the world in recent years has been recorded from the dog.

Habits and Life History. The eggs (Fig. 37 (*a*)) are attached by the females to the hair or feathers of the host. The young lice on hatching closely resemble the adults, differing in size, in the degree of chitinization,

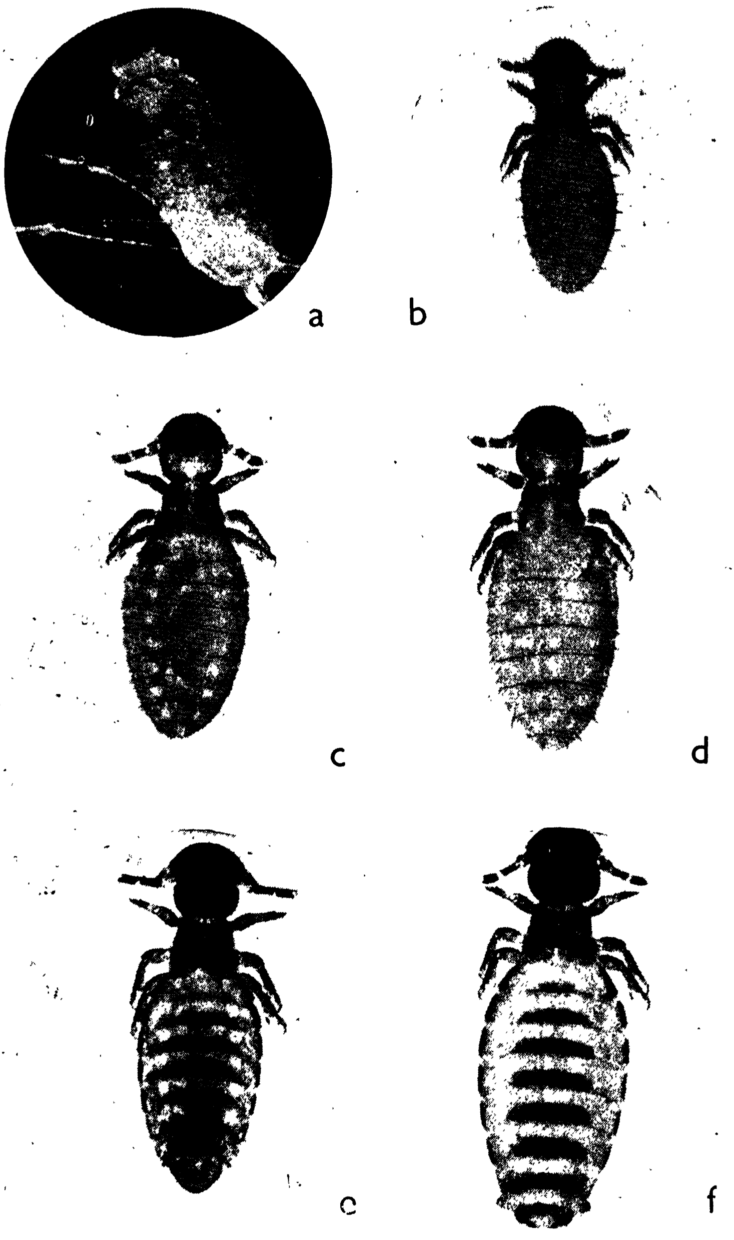

Fig. 37. The life cycle of a louse, *Damalinia ovis*. (*a*) Egg; (*b*) first stage nymph; (*c*) second stage nymph; (*d*) third stage nymph; (*e*) adult male; (*f*) adult female. (All stages at same magnification.)

(*After Scott and Parrish.*

and in not being sexually mature (Fig. 37 (*b*)). The adult stage (Fig. 37 (*e*), (*f*)) is reached after three ecdyses, each nymphal stage being readily distinguished by its size, the width of the head capsule, and the chitinization of the lateral margins of the abdominal segments (Fig. 37 (*b*)—(*d*)). There is some evidence that one species, *Damalinia bovis* (Linn.), may reproduce mainly by parthenogenesis.

Lice Infesting Cattle

Six species of lice are known to infest cattle, namely, the biting louse, *Damalinia bovis* (Linn.), the short-nosed sucking louse or blue louse, *Haematopinus eurysternus* (Nitzsch), the tropical sucking louse or tail-switch louse, *H. quadripertusus* Fahrenholz, the buffalo louse, *H. tuberculatus* (Burmeister), the long-nosed sucking louse, *Linognathus vituli* (Linn.), and the tubercle-bearing or little blue sucking louse, *Solenopotes capillatus* (Enderlein). All of these occur in Australia.

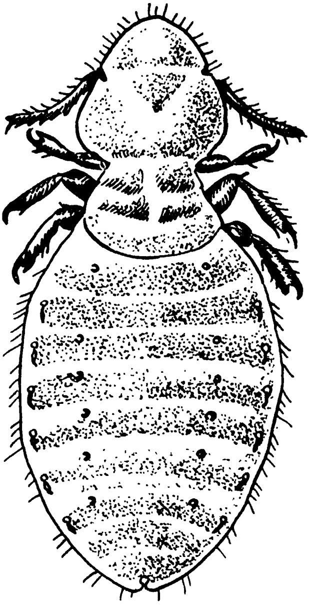

Fig. 38. The biting louse of cattle, *Damalinia bovis*.
(*After Helmsing.*)

The Biting Louse (*D. bovis*—Fig. 38). This cosmopolitan species is reddish-brown in colour, with a broad, flat head, and measures up to 1·75 millimetres. It occurs on cattle of all ages and breeds, but is more frequent among dairy cattle than among beef cattle. The areas of the body most favoured include the top of the head, the neck, the shoulders, the withers, along the back, and the rump. Very heavy infestations may spread to all parts of the hair coat. During those periods of the year when infestations are very light or even apparently absent, lice may be found in the long, tight, curly hair of the forehead and in the hair of the tail.

The eggs are laid on the hairs close to the skin and are glued to the hair by the posterior fourth. The average life cycle periods are as follows:

Period	*Days*
Incubation	8
1st nymphal instar	7
2nd nymphal instar	5.5
3rd nymphal instar	6
Pre-oviposition	3
Life cycle, egg to adult ...	29

Adult females will live as long as 42 days on the host and will deposit eggs at the rate of one every 35 hours or thereabouts. A female is capable of laying up to 30 eggs during her lifetime, though the average number deposited is probably less than this, about 20. Males are comparatively few, and one observer goes so far as to say that the normal method of reproduction is by parthenogenesis, though the presence of males may be necessary for rapid increases in the population.

The Buffalo Louse (*H. tuberculatus*). This rather large louse, which measures up to 5.5 millimetres, was originally described from the Indian buffalo, *Bos bubalus*, on which it has been recorded from many parts of the world. It has been found infesting camels and cattle in Australia, but is not considered as of any great importance. The eggs hatch in 9 to 13 days and each instar is completed in 3 to 4 days. The pre-oviposition period is 3 days, the complete cycle, hatching to adult, being completed in 9 to 11 days.

The Long-nosed Louse (*L. vituli*—Fig. 39). In this louse, which attains a length of 2.5 millimetres, the first pair of legs are distinctly smaller than the second and third pairs. The head is very long and narrow, being about twice as long as broad. The coloration in this smaller, slender species

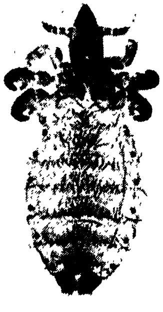

Fig. 39. The long-nosed cattle louse, *Linognathus vituli.*
(*After Keith.*)

is much the same as in *H. eurysternus*. It is seen mostly among dairy cattle and is common on young stock. The sites of infestation are usually the neck, particularly the sides, the back, ribs, udder, rump, perineum, and belly.

The eggs are elongate-oval in shape, and measure 0·95 millimetre by 0·39 millimetre. They hatch in 8 to 13 days, the life cycle, egg to egg, occupying 21 to 30 days.

The Tubercle-bearing or Little Blue Louse (*S. capillatus*—Fig. 40). This is the smallest of the sucking lice and is about 1·25 to 1·75 millimetres long. It is recorded from cattle in the United States, Canada, England, Europe, and Australia. It has a brownish head and thorax and a bluish abdomen. It resembles *L. vituli* in possessing forelegs which are smaller than the mid and hind pairs, but can be readily distinguished from this species by the head, which is short, broad, and blunt, by the abdominal spiracles, which are situated on tubercles, and by the presence of a single transverse row of setae on each of the abdominal segments.

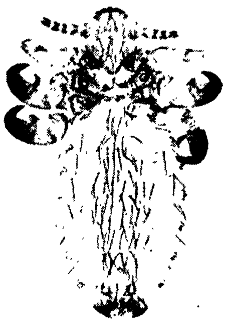

Fig. 40. The little blue cattle louse, *Solenopotes capillatus*.
(*After Keith.*)

S. capillatus occurs in conspicuous clusters and infests the neck, head, shoulders, dewlap, back, anus, and tail. During the summer, when lice are inactive, they may be found on the brisket. Very little is known of its life cycle.

The Short-nosed Louse or Blue Louse (*H. eurysternus*—Fig. 41). This species is also world-wide in its distribution and occurs to a greater extent on grown cattle, particularly the beef breeds, than on young cattle. The female is about 3·5 millimetres in length, and both sexes have a brownish head—bluntly pointed and about three-quarters as wide as long—brownish legs, and a dark-bluish abdomen. This species may be confused with *H. quadripertusus* and *H. tuberculatus*, from which it may be distinguished by the characters given in the key (see p. 36). The egg measures 1·09 millimetres by 0·51 millimetre at its widest point and is usually opaque, whitish in colour, sometimes brownish. The principal breeding areas are the top of the neck, the base of the horns, the brisket, and the tail, but in heavy infestations breeding may occur anywhere on the hair coat. The life cycle periods are as follows:

Period	*Days*
Incubation	9 to 19 (average 12)
1st nymphal instar	3 to 5 (average 4)
2nd nymphal instar ...	3 to 5 (average 4)
3rd nymphal instar	3 to 6 (average 4)
Pre-oviposition	2 to 7 (average 4)
Life cycle, egg to egg ...	20 to 41 (average 28)

Males may live up to ten days and females up to sixteen days. During her lifetime a female may lay as many as 35 to 50 eggs.

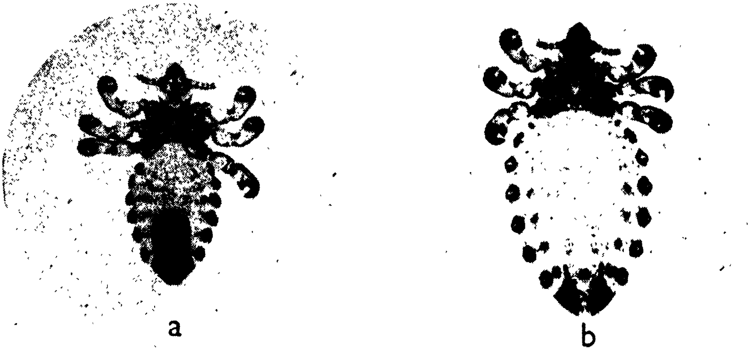

Fig. 41. The short-nosed cattle louse, *Haematopinus eurysternus*. (*a*) Male; (*b*) female.

(*After Keith.*)

During the winter, when the lice are active, they may be found in numbers on the face, particularly round the eyes and at the base of the horns, on the neck and dewlap, the rump, the base and switch of the tail, the escutcheon, and the scrotum. In very heavy infestations any part of the body may be attacked. In the summer they are seen only near the tips of the ears, around the bases of the horns, and at the butt of the tail.

The Tail-switch Louse (*H. quadripertusus*). This species occurs in West Africa, the West Indies, the southern United States, Australia, and New Britain, and will probably be found in other tropical areas. In Australia it has so far been seen only in the tropical parts of Queensland, though no doubt it occurs also in the Northern Territory and in the north of Western Australia.

This is a large, dark species, previously referred to in Australia as the large, dark, tropical form of *H. eurysternus*. It is up to 4·5 millimetres long, the head, thorax, and legs being dark brown and the abdomen a dark grey. The adults occur mainly in the tail-switch, but may also be found round the eyes and in the long hair of the ears. The eggs are laid almost exclusively in the tail-switch, and the nymphs migrate to the soft skin round the anus, vulva, and eyes. The incubation period is about 11 days. The eggs are similar in appearance to those of *L. vituli*, but measure only 0·76 millimetre by 0·32 millimetre.

Transmission. Undoubtedly the usual method of spread of lice through a herd of cattle is by contact between animals, and it has been observed that "sexually mature lice instinctively move outward on the hair when a lousy animal is rubbed by another". The danger of infestations arising from eggs and lice on detached hairs is not considered important, because under such conditions eggs do not hatch and lice live only a few days.

Seasonal Prevalence. Lice may be present at any time of the year, but it is only under certain conditions that they reach serious proportions. Lice populations are always high during the winter and early spring, but may also occur on stalled cattle during the summer. Several factors have been mentioned as controlling their abundance, such as the state of nutrition of the host, the condition of the skin and coat, the light-intensity, and the temperature of the skin surface. Although nutrition has proved to be a controlling factor with lice on rats, there is no evidence to show that a similar relationship exists with lice on cattle. Furthermore, the rapidity with which infestations may be built up on fat cattle that are stalled makes it apparent that factors other than nutrition are directly concerned. It has been suggested that louse populations are controlled by light-intensity, though this factor hardly applies in Australia, where there are many bright, sunny days during the winter, when the lice on cattle in pastures attain their maximum abundance. Another opinion is that the temperature of the skin surface is the controlling factor. In *D. bovis*, for example, the temperature limits for population maintenance are between 90° F. and 100° F., whereas in the summer, in animals exposed to bright sunlight, the skin temperature may rise to 125° F., which is quickly lethal to this species.

Importance. There are few countries in which lice are not serious parasites. Both beef and dairy cattle of all ages may be affected. *H. eurysternus* is chiefly concerned with beef cattle and *L. vituli* and *D. bovis* with dairy stock. *S. capillatus* may also occur in serious proportions, particularly on dairy animals, whilst preliminary reports indicate that *H. quadripertusus* may be even more severe in its attack than *H. eurysternus*.

Sucking lice are in general regarded as being responsible for greater losses than biting lice. The former cause considerably more irritation with their habit of feeding in clusters or colonies, and of piercing the skin and sucking up the blood and fluids. Biting lice are less irritating, since they feed on the scurf, hair, etc., on the skin surface.

In heavily infested animals, which are constantly rubbing and scratching, there is loss of hair, the skin becomes scaly and raw patches appear. It is generally considered that there is a loss in milk production, and gains in weight are retarded. Under northern Australian conditions the lice populations attain their maximum intensity at a time when the nutritive state of the pastures is at its worst, and when cattle find it very difficult to secure sufficient nourishment for bodily requirements. There seems to be no doubt that under these conditions lice become very important.

Animals that are stalled for any length of time and not exercised or groomed, develop a scurfy condition of the skin that causes itching and scratching. This condition simulates lice infestation and must be differentiated from it.

Control. Of the various insecticides in use against cattle lice, DDT and BHC have been given most attention. A single treatment with a 0·5 per cent para para DDT aqueous preparation has been shown to eradicate both biting and sucking lice. While lower concentrations of 0·25 to 0·35 per cent will eradicate *L. vituli* and *D. bovis* after one application, two treatments at an interval of 14 days are required for *H. eurysternus*. *H. quadripertusus* is more resistant, and requires a concentration of 1·5 to 2·0 per cent. With BHC employed as a dip, wash, or spray a concentration of 0·05 per cent gamma isomer will kill all stages except the egg. Concentration of 0·1 per cent gamma isomer is claimed to be ovicidal. Chlordane (0·5 per cent), toxaphene (0·5 per cent) and methoxychlor (0·5 per cent) are also said to be very efficient when used as emulsions or suspensions. Dusts are not as effective as emulsions or suspensions, and concentrations of 5 per cent DDT and of 0·5 to 1 per cent gamma BHC are necessary for equivalent results. Derris dust (10 per cent) or derris suspension (1 pound of derris (5 per cent rotenone) per 100 gallons) is also recommended, but has little residual toxicity and two or more treatments are required.

Sodium arsenite, 0·2 per cent As_2O_3, is effective only against *D. bovis*. Nicotine sulphate, employed at the rate of 5 millilitres per gallon of wash, will kill adults and nymphs of all species. Since neither of these insecticides has any residual toxicity, at least two treatments at a 14 day interval are necessary for eradication.

Dusts have their uses where for any reason it is undesirable to wet the animals—for example, during very cold weather. Under Australian conditions, plunge dips and sprays are more practicable, though with small numbers of animals the insecticide may be applied with a cloth or brush. When using sprays it is essential to obtain thorough wetting, which can be secured only by using high pressures or, alternatively, a large quantity of fluid, say 2 to 3 gallons for a large bull.

Where cattle are treated regularly in DDT or BHC for cattle-tick control, lice cease to be a problem. Where lice are prevalent it is essential that animals be treated during the autumn so that they begin the winter free from these parasites. The muster for treatment must be complete, for untreated animals will quickly reinfest the rest of the herd.

Lice Infesting the Horse

Three species of lice infest the horse, namely, the biting lice, *Bovicola equi* (Linn.) and *B. pilosus* (Paiget), and the sucking louse, *Haematopinus asini* (Linn.).

Biting Lice (*B. equi* (Fig. 42) *and B. pilosus*). These are typical biting lice in appearance, up to 2 millimetres long, and very similar to one another. In *B. equi* the front of the head is semicircular and the antennae arise well back on the head. The prothorax is narrower than the head, and the abdomen is covered with very short hairs, except posteriorly. In *B. pilosus* the antennae are almost in line with the front of the head, the prothorax is as wide as the head, and the abdomen is thickly beset with long hairs. The former is the more common species, *B. pilosus* being recorded only from Europe and the United States.

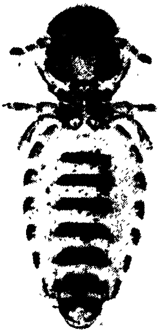

Fig. 42. A biting louse of the horse, *Bovicola equi.*
(*After Keith.*)

Biting lice prefer the sides of the neck, round the flank, and the base of the tail. The eggs hatch in 8 to 10 days.

The Sucking Louse (*H. asini*—Fig. 43). This species has a long narrow head and is up to 3·5 millimetres long. It favours the roots of the mane and of the forelock, round the butt of the tail, and above the hooves. The eggs hatch in 12 to 14 days, and 11 to 12 days later the young lice are mature.

Importance. The parasites increase rapidly during the winter when the hair is long. Poverty is also associated with heavy infestations. The

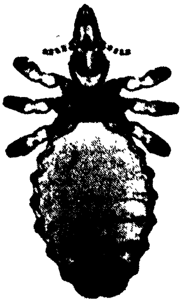

Fig. 43. The sucking louse of the horse, *Haematopinus asini.*
(*After Keith.*)

irritation causes the animal to stamp and kick, the hair is rubbed off in patches, and the skin is bruised and lacerated.

Biting lice have been incriminated as vectors of infectious anaemia.

Control. The treatments recommended for the control of cattle lice will also be effective against lice infesting the horse.

Lice Infesting the Pig

Only one species of louse, *Haematopinus suis* (Linn.) (Fig. 44), occurs on the pig, and it is the largest sucking louse attacking domestic animals. The colour is greyish brown with brown and black markings. The lice are most frequently found in the folds of the neck and jowl, on the inside and base of the ears, on the inside of the legs, on the flanks, and on the back.

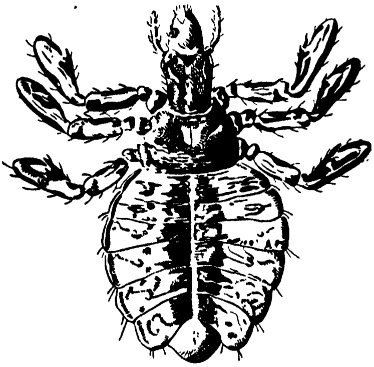

Fig. 44. The sucking louse of the pig, *Haematopinus suis.*
(*After Helmsing.*)

The egg is 1·5 to 1·75 millimetres long by 0·5 to 0·75 millimetre at its widest part, and when laid is pearly-white, but as development proceeds it becomes light amber in colour. The egg is attached by the female to the bristles close to the pig's skin, particularly in the region of the lower half of the sides, the back of the ears, the neck, shoulders, and flanks. Each female lays 3 to 6 eggs a day, and as many as 90 eggs in her lifetime. These hatch in 12 to 14 days, though in cool weather the incubation period may be prolonged to 20 days. The young lice suck the more tender parts of the body and are mature in about 10 days, the first eggs being deposited 2 days later. The life cycle, from egg to egg, occupies 28 to 33 days.

Importance. The scratching and rubbing so conspicuous in infested pigs is ample evidence of the irritation and annoyance caused by these parasites. This may be so severe in young pigs as to arrest their growth. Attempts to relieve the irritation result in hairless, torn, and bleeding areas round which the lice concentrate.

Pig lice have been incriminated as vectors of swine fever. This disease may be established by the ingestion of lice or by the passage of lice from affected to healthy animals.

Control. Prior to the advent of the newer insecticides, oily materials were recommended for the control of pig lice. Crude oil applied either as a hand dressing or in a 3- to 6-inch layer on water in a dip and repeated after an interval of 15 days is one of the most effective of these treatments. It should be remembered that if pigs are permitted to roam in the hot sun after this treatment they may become scalded and blistered, particularly the white breeds. It is therefore advisable to keep treated animals in the shade until most of the oil has disappeared, or, better still, to carry out treatment late in the afternoon.

DDT in concentrations of 0·2 to 1·0 per cent as an emulsion or suspension will kill all adults and nymphs, and the higher concentration will keep the animals free from lice for periods up to three weeks. Owing to the movements of lice over the body there is no need to treat the whole of the skin surface. To secure good control, pigs can simply be herded into a corner and sprayed.

BHC in concentrations as low as 0·05 per cent gamma isomer gives very good results. Chlordane, 0·25 per cent, toxaphene, 0·2 per cent, and methoxychlor, 0·2 per cent, also appear very effective.

Lice Infesting the Sheep

The species of lice infesting the sheep include the biting louse or body louse, *Damalinia ovis* (Linn.), the foot louse, *Linognathus pedalis* (Osborn), the face louse, *L. ovillus* (Neumann), and the goat-sucking louse, *L. stenopsis* (Burn.). The latter usually occurs on goats, but is recorded from sheep in Africa, India, the United States, and Transcaucasia.

The Body Louse (*D. ovis*—Figs 37, 45). This is a small, pale species, up to 1.8 millimetres in length, with a broad, reddish head. It is world-wide in its distribution, and occurs throughout Australia in the sheep-raising areas of all the States, though it is less frequent in, and sometimes absent from the drier inland districts.

Habits and Life History. On the sheep the heaviest infestations occur along the mid-dorsal line and down the sides. The lower portions of the body are not usually favoured, though on occasions large numbers of lice may be found on the underside of the neck. There is a marked seasonal fluctuation in numbers, the heaviest infestations being seen during the winter and early spring. In general, poor sheep carry the largest populations, which may remain throughout the year. The average life cycle periods are as follows:

Period	*Days*
Incubation	9 to 10
1st nymphal instar ...	7
2nd nymphal instar ...	5
3rd nymphal instar ...	9
Pre-oviposition	3
Life cycle, egg to egg ...	34

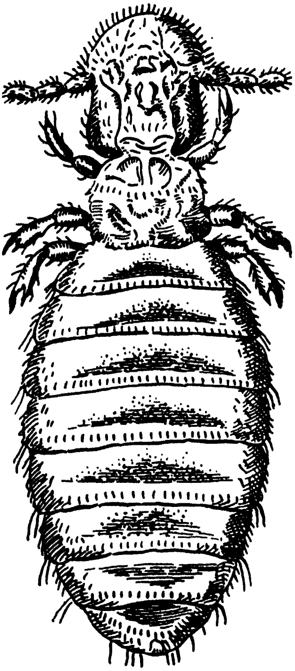

Fig. 45. The body louse of sheep, *Damalinia ovis.*

(*After Helmsing.*)

The Foot Louse (*L. pedalis*—Fig. 46). This sucking louse is about 2 millimetres in length, the head being short and about as wide as it is long. The abdomen is thickly covered with long slender bristles, without any obvious arrangement into rows. It is recorded from England, North and South America, South Africa, New Zealand, and Australia. In Australia it is found in all States, and it tends to extend into the drier parts of the sheep areas to a greater extent than *D. ovis.*

Habits and Life History. The foot louse infests the lower, hairy parts of the body, namely the shanks, belly, and scrotum. The lice are most active from June to November. During the warmer months of the year the populations dwindle and lice may be difficult to find, though they probably survive these adverse periods by sheltering in such places as between the claws. The heaviest infestations are seen on young sheep, and lambs may be infested within 48 hours of birth. Rams appear particularly favoured, especially if stalled.

The eggs are laid on the hairs and are deposited—for a time at least—at the rate of one per day. The average life cycle periods are as follows:

Period	*Days*
Incubation	17
1st nymphal instar	7
2nd nymphal instar	7
3rd nymphal instar	7
Pre-oviposition	5
Life cycle, egg to egg	43

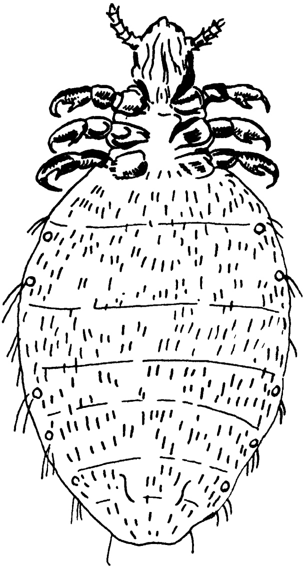

Fig. 46. The foot louse of sheep, *Linognathus pedalis.*
(*After Helmsing.*)

The Face Louse (*L. ovillus*—Fig. 47). This is a slightly larger species than *L. pedalis* and measures up to 2·5 millimetres. It has a relatively large head, which is longer than it is broad. The abdomen is hairy, the hairs being arranged in well-defined rows on the dorsum, with a longitudinal bare area on each side. It is recorded from Australia, New Zealand, the United States, and Great Britain. The Australian records are somewhat confusing, since most of them refer to *L. pedalis*, but *L. ovillus* is said to occur in New South Wales, Tasmania, and South Australia.

This species infests the region of the face. Nothing is known of its biology.

Transmission of Sheep Lice. In the case of *D. ovis* the main method of spread is undoubtedly by contact between animals. Eggs in detached pieces of wool do not hatch, and adult lice—even under the most favourable conditions—live only a few days. Such detached lice are therefore of little danger in a paddock, but may be a source of infestation in a shearing shed or yards where lousy sheep have been a day or two previously.

The main method of spread of *L. pedalis* is not clear. Contact between animals may not be as important as is the case with *D. ovis*. Adult *L. pedalis* are capable of surviving off the sheep for as long as 18 days under favourable conditions, and there is evidence that transmission to clean sheep can occur from a pasture on which infested sheep have been running. The length of time such a pasture may remain contaminated depends on the conditions that influence the survival of the lice.

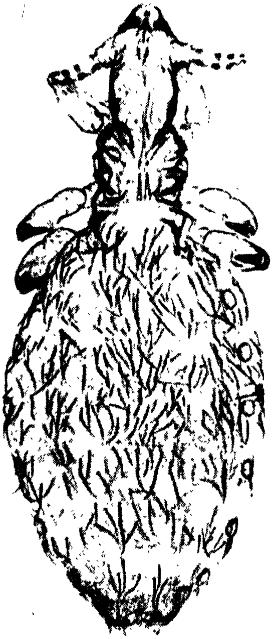

Fig. 47. The face louse of sheep, *Linognathus ovillus*.
(*After Keith.*)

Importance of Sheep Lice. *L. ovillus* is a rare parasite in Australia and has no economic importance. Heavy infestations of *L. pedalis* are infrequent and usually confined to only a few individuals in a flock. The foot louse appears to be of greatest significance among rams, particularly when stalled. The severe irritation causes the animals to stamp and kick and may result in loss of condition. *D. ovis* is the most important species and is a cause of serious economic loss. The fleece of heavily infested animals becomes ragged and torn and much reduced in value. Loss of condition may also occur.

Control of Sheep Lice. Where large numbers of sheep are concerned, lice can usually be controlled by the application of an insecticide in liquid form, so as to wet the fleece and reach the skin where the lice occur. In some countries, where wetting of the fleece is considered undesirable and where only small flocks are to be treated, dusting with powder insecticides is employed. In Australia no attempt has been made to determine the efficiency of dusts, which could be used, for example, on valuable stud stock and on rams infested with *L. pedalis*. Recent work in the United States indicates that power dusting can be effectively used for large flocks, and 5 per cent DDT has proved satisfactory in preliminary trials.

In Australia, treatment is given either in swim-through or straight-swim dips or by means of shower sprays. Swim-through dips (Fig. 48) consist of a concrete or iron tank up to about 70 feet in length, 5 feet deep, with sloping sides 12 inches wide at the bottom to 2 feet wide at water-level, with a steeply inclined entrance and a less steeply inclined walk-out. These dips are usually built into the ground and are approached by a narrow race with a draining pen at the exit end, where the sheep are held after immersion until all excess fluid drains from the body. This fluid flows back into the dip through a sump. The length of the dip is important and should be such that at the end of its swim the

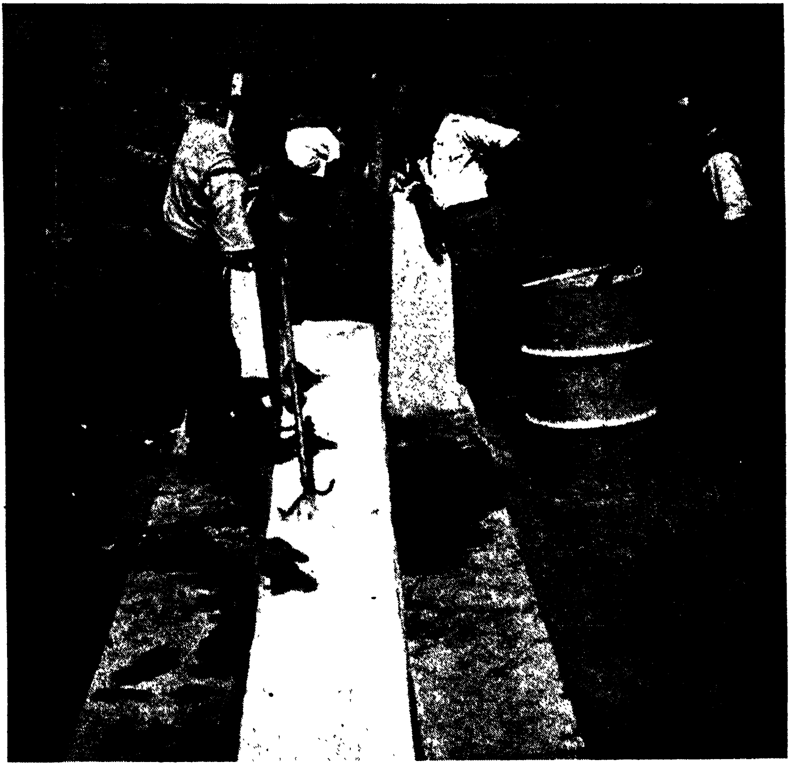

Fig. 48. Straight-swim or plunge dip for treating sheep for lice, ked, and other external parasites.

(*After Moule*.

animal is thoroughly saturated. During its passage through the dip the animal's head is immersed to ensure complete wetting.

Shower sprays or shower dips (Fig. 49) have an enclosed pen into which the sheep are driven. The insecticide is then applied to the animals through a series of spray nozzles with a power-driven pump. The nozzles are attached to pipes above and on the floor of the pen. The top sprays may be on a rotating arm. The excess fluid is returned to the pump after filtering.

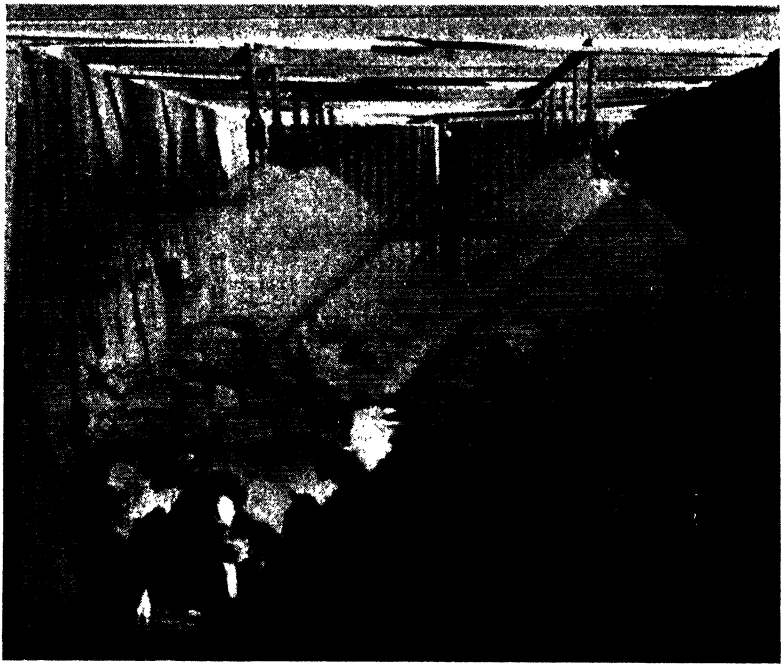

Fig. 49. Shower dip for treating sheep for lice, ked, and other external parasites. (*After Moule.*)

There are also other types of dips, used overseas, such as the island or ring dips, the U-shaped dip, and the primitive cage dip.

The amount of fluid retained by a sheep when passing through a dip depends on the size of the animal and the growth of the fleece. Freshly shorn sheep retain a quarter of a gallon to half a gallon of fluid, animals with 2 to 3 months' wool three-quarters of a gallon to one gallon, whilst full-woolled sheep retain up to two gallons.

Wetting of the entire animal is essential to control biting lice, but for foot lice it is necessary to treat only the lower parts. For this, a walk-through dip to the required depth would be adequate, but for practical purposes it is usual to employ the ordinary swim-through dip.

Insecticides Employed. The various insecticides in use throughout the world include sulphur, arsenic, phenols and cresols, rotenone, and the chlorinated hydrocarbons, particularly DDT and BHC. Sulphur has been recommended in the United States for both biting and sucking lice as 325-mesh wettable sulphur. It is present in many of the powder dips sold in Australia, but in the form employed its insecticidal value is negligible. Sulphur has very little residual toxicity.

Arsenic is employed as sodium arsenite at a concentration of 0·2 per cent As_2O_3. It is very effective against biting lice, even at 0·1 per cent As_2O_3, and possesses sufficient residual toxicity to kill lice hatching from the eggs that are unharmed. It is not, however, effective against foot lice. It is sometimes used in combination with sulphur, but these compounds are not as valuable as sodium arsenite alone.

Rotenone is used as a suspension or in combination with arsenic or phenols at a concentration of 0·0025 per cent. It has little residual toxicity, and under Australian conditions has given somewhat variable results in single treatments. Reports from the United States are more favourable, where one dipping in 6 ounces of derris or cubé (5 per cent rotenone) per 100 gallons has given complete eradication.

The phenols are generally used as emulsions containing 0·4 per cent phenols or other suitable coal-tar distillates, frequently incorporated with arsenic or rotenone. These phenolic dips are not considered very effective against either body lice or foot lice.

A single dipping in 0·1 per cent para para isomer DDT or 0·01 per cent gamma isomer BHC will eradicate body lice. These are well above the minimum effective concentrations, but allowance is made for the "stripping" or exhaustion of these insecticides, which occurs during treatment. "Stripping" refers to the decrease in concentration of the insecticide that takes place as treatment proceeds. It is less obvious with colloidal-type formulations than with emulsions or dispersed powder-type formulations, and occurs more readily in shower dips than in swim-through dips. It has also been seen with insoluble arsenic compounds, and probably occurs with derris. DDT at a concentration of 0·5 per cent has given effective results as a single treatment for foot lice, and BHC at concentrations of about 0·0325 per cent gamma isomer is promising.

Precautions. Whichever insecticide is used, its efficiency against lice and the safety of the sheep depend upon a thorough understanding of dipping practice. This entails the careful observance of certain essential precautions, which are detailed below:

1. Since lice infestation is a scheduled disease in all States, it may be necessary to dip sheep irrespective of the length of the fleece. In practice, however, dipping shortly after shearing has given better results than dipping when the wool is fairly long. Dipping a recently shorn sheep ensures better wetting, and in the case of body lice the shearing reduces the lice population by removing the protective cover. Four to six weeks after shearing is the usual time for dipping. Where arsenic is used it is essential that all shear-cuts heal before treatment, otherwise there may be serious ill-effects. Neither BHC nor DDT is bactericidal, and pathogenic

organisms may possibly enter open wounds and abrasions during dipping. Indeed, in both Australia and New Zealand cases have occurred where *Erisypelothrix rusiopathiae*, an organism causing lameness and other troubles in sheep, has gained entrance into the body in this way after dipping in BHC. Infections with anaerobic organisms have also been seen. These infections can be prevented by the addition of copper sulphate to the dip, at a concentration of 1 in 5000.

2. The mixing of the dip should strictly follow the makers' directions, and accurate measures must be used. The dip should be thoroughly mixed by using a plunger or rake, particular attention being paid to the entrance, where the material tends to accumulate. Clean dips are most efficient, and dirty dips may affect the fleece. Remove all scum.

3. Dipping should not take place in very cold weather, otherwise losses may occur. Select bright sunny days, and time the treatment so that the sheep are dry before nightfall. Dipping should also be avoided in wet weather.

4. It is important that the sheep be wetted to the skin. The time required for thorough saturation depends on the length and density of the fleece; with sheep four to six weeks off shears, about one minute is needed. Dip the ewes and lambs separately, handling the rams with care. Rough treatment and hurry-up methods give poor results, and may lead to losses through the fluid's entering the lungs. It is risky to dip overheated and thirsty sheep.

After adequate drainage, which requires at least 7 minutes, the animals should be driven quietly away.

5. A complete muster is essential, for any sheep missed will quickly reinfest the flock.

The application of DDT and BHC as a fog to infested sheep confined in a tent or shed has been given some attention in Australia. This has proved satisfactory with sheep off shears, but is not effective when there is several months growth of wool present.

Lice Infesting the Goat

Several species of lice infest goats, the species occurring on the common goat and angora goat usually being distinct, though sometimes there is some intermingling of species when these two hosts are running together.

Damalinia caprae (Gurlt.) (Fig. 50) is the biting louse of the common goat, whilst *D. limbata* (Gervais), *D. penecillata* (Paiget), and *Holakarticos crassipes* (Rudow) are the biting lice of the angora goat.

The sucking louse, *Linognathus stenopsis* (Burm.) (Fig. 51) (*L. africanus* (Kellog and Paine)) is found on both hosts, and is also recorded from sheep in various parts of the world, such as Africa, India, the United States, and Transcaucasia.

The biting lice are all very similar in appearance, and difficult to distinguish from one another. The head and thorax are reddish and the abdomen is pale with median dark bands. *D. penecillata* is a hairy species. Only *D. caprae* is recorded from Australia.

The sucking louse has a long, pointed head with broad temples, narrowing rapidly behind. The abdomen is elongate-oval, with the spiracles opening near the lateral margins of the segments. The species is up to 3·5 millimetres long and occurs in Australia.

Importance. The effects of moderate to heavy infestations are similar to those reported for other domestic animals. The sucking louse is more severe in its attack than the biting lice, and may cause the formation of scabby, bleeding areas. Among angora goats, biting lice seriously damage the mohair. Not only is the fleece broken and made ragged by the animal's scratching and rubbing, but the lice themselves are capable of biting through the hairs with their mandibles.

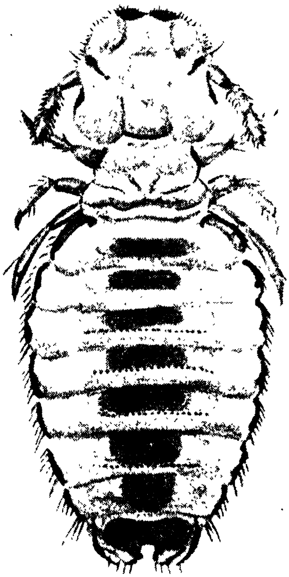

Fig. 50. A biting louse of the goat, *Damalinia caprae.* (*After Helmsing.*)

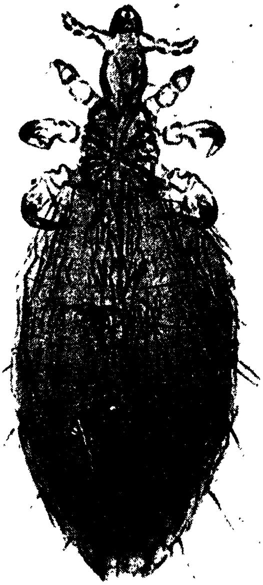

Fig. 51. The sucking louse of the goat, *Linognathus stenopsis.* (*After Helmsing.*)

Control. The measures recommended for the control of lice in sheep will also control lice in goats.

Lice Infesting the Dog

Dogs are infested by two species of biting lice, *Trichodectes canis* (De Geer) and *Heterodoxus longitarsus* (Paiget), and by a sucking louse, *Linognathus setosus* (v. Olfers) (syn. *L. piliferus*).

The Common Biting Louse (*T. canis*—Fig. 52). This is a short, broad species between 1 and 2 millimetres in length, the head being subquadrangular in shape, broader than long, and possessing short, thick antennae. This louse is yellowish with dark markings.

The Kangaroo Louse (*H. longitarsus*—Fig. 53). This species was originally recorded from kangaroos, but has succeeded in establishing itself on dogs in several countries, and is an important parasite of these animals in temperate and tropical America and Australia. It is a slender, yellowish species, about 3 millimetres in length. The head is triangular, with a rounded forehead and subangulate temporal lobes. The antennae are five-segmented and the palpi four-segmented. There is a pair of strong, ventral, spine-like processes arising from the base of the palpi. The eggs are elongate-oval, with a sculptured shell, and a short, curved filament arises from the operculum.

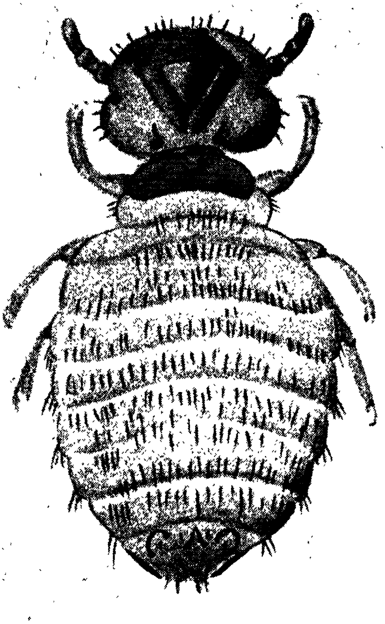

Fig. 52. The biting louse of the dog, *Trichodectes canis.*
(*After Helmsing.*)

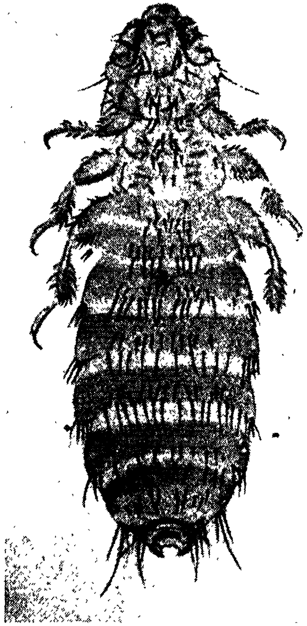

Fig. 53. The kangaroo louse, *Heterodoxus longitarsus.*
(*After Helmsing.*)

This louse has also been recorded from the fox, jackal, and coyote.

The Sucking Louse (*L. setosus*—Fig. 54). This louse has a blunt, rounded head, about as wide as it is long. The abdomen is thickly covered with fine hairs and wart-like excrescences. The louse measures about

1·5 millimetres, and when fully fed is bluish in colour. It also occurs on the fox and coyote.

Importance. Biting lice are most prevalent on puppies and aged dogs, and, in general, on animals that are unable to keep themselves clean. The sucking species is usually more common on long-haired than on short-haired dogs. The irritation and annoyance caused by a heavy infestation is pitiful to see, the animal constantly scratching and whining. Young puppies may be literally worried to death.

T. canis is an intermediate host of the dog tapeworm, *Dipylidium caninum.*

Control. Lice on dogs are not difficult to control, and the treatments recommended for the control of fleas on dogs (see p. 62) will also control lice, DDT being particularly effective.

Lice Infesting the Cat

Only one species of louse is found on cats, namely *Felicola subrostrata* (Nitzsch) (Fig. 55), a biting louse. The head is pointed, with a median longitudinal groove on its underside. The insect adheres to the hair of the coat, which is held closely in this groove. The abdomen is stout

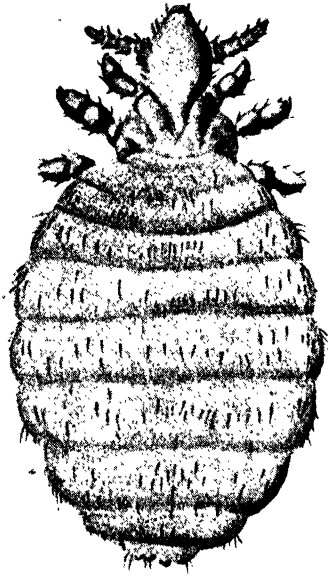

Fig. 54. The sucking louse of the dog, *Linognathus setosus.*
(*After Helmsing.*)

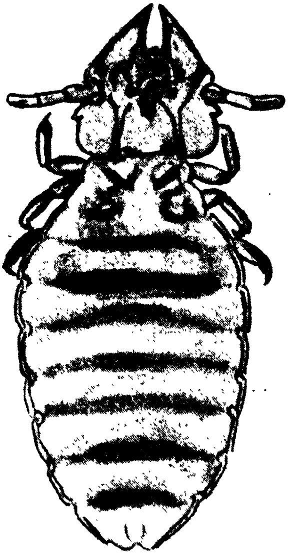

Fig. 55. The biting louse of the cat, *Felicola subrostrata.*
(*After Helmsing.*)

and banded. The insect is very small, being little more than 1 millimetre in length.

This biting louse appears to be of minor importance and is usually found in numbers only on cats that, because of ill-health or age, are unable to keep their coats clean. It is seen most frequently on aged, long-haired cats.

Control. DDT and BHC dusts are dangerous if used on cats. The derris and pyrethrum dusts recommended on p. 62 for controlling fleas will control this louse.

Poultry Lice

Lice Infesting the Fowl

The Wing Louse (*Lipeurus caponis* (**Linn.**)—Fig. 56). This is not a very active species, and may be seen resting between the barbules of the wing and tail feathers and sometimes also on the back of the neck. It is a slender louse about 2 millimetres in length, with narrow dark margins to the body, and a dark central stripe on the abdomen. The eggs are elongate and whitish and are laid between the barbules of the feathers.

The Head Louse (*L. heterographus* (**Nitzsch**)—Fig. 57). This louse is about 2·5 millimetres in length, and is found on the skin and among the

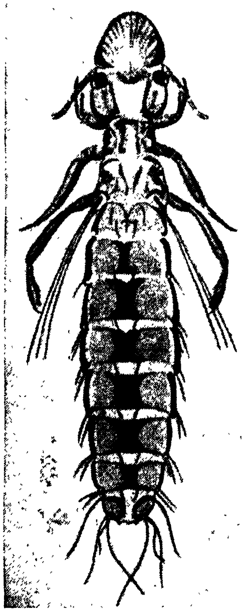

Fig. 56. The wing louse of the fowl, *Lipeurus caponis.* (*After Helmsing.*

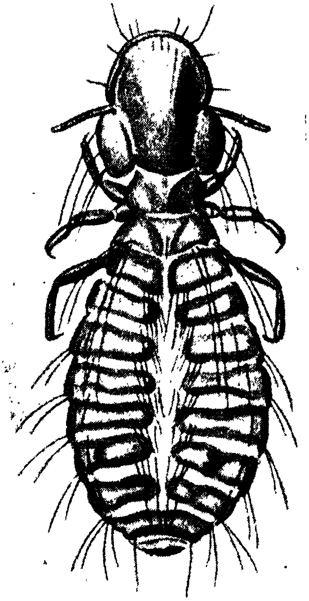

Fig. 57. The head louse of the fowl, *Lipeurus heterographus.* (*After Helmsing.*

feathers of the head and neck, and occasionally elsewhere on the body. The head is a little longer than it is broad, and the antennae of the male are long and thick, with a posterior process. The abdomen is elongate in the male and somewhat barrel-shaped in the female, and has conspicuous, dark, lateral markings.

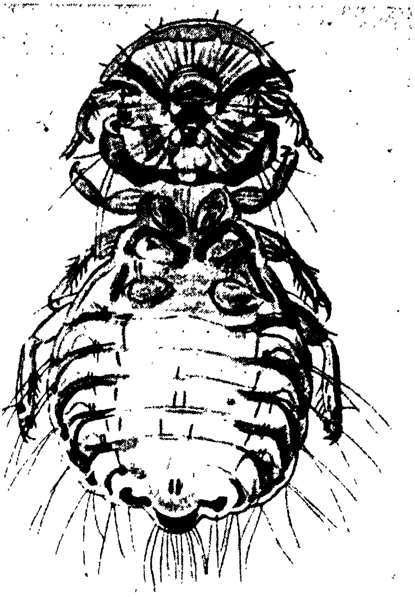

Fig. 58. The brown louse of the fowl, *Goniodes dissimilis.*
(*After Helmsing.*)

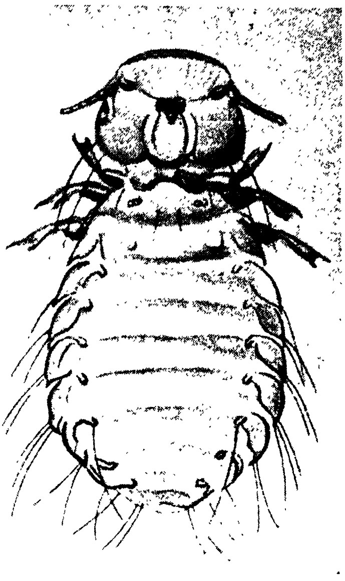

Fig. 59. The fluff louse of the fowl, *Goniocotes gallinae.*
(*After Helmsing.*

The pearly-white eggs are laid close to the skin on the down or small feathers of the head, and hatch in four to seven days. The lice reach maturity in 25 to 42 days.

The Brown Louse (*Goniodes dissimilis* **Nitzsch**—Fig. 58). The brown louse is a stout red-brown species, 2·5 millimetres in length, which infests the feathers of the body. The head has a circular front and angulate temples. The abdomen is broad, with confluent side-markings and dark transverse bands. It is most common among grown birds.

The Fluff Louse (*Goniocotes gallinae* **(De Geer)**.—Fig. 59). One of the smallest of the lice, this species is found among the fluff at the base of the feathers, chiefly on the back and rump. The head is circular in front, and a little narrower than it is long. The temples are furnished with long bristles. It also occurs on pheasants.

The Large Hen Louse (*G. gigas* **Tasch**). This species is seen both on the body and among the feathers, but is rarely present in large numbers. It measures up to 5 millimetres. The head has a rounded front and angulate temples. The head, thorax, and legs are yellowish with dark margins, and the abdomen has dark lateral margins.

The Shaft Louse (*Menopon gallinae* (Linn.)—Fig. 60). This louse, which attains a length of about 2 millimetres, has a habit of resting on the shafts of the feathers, running onto the body when disturbed. The species is rarely seen on young birds until the feathers appear. The head is broadest posteriorly, with a rounded forehead and rounded temples. The thoracic and abdominal segments each have one row of dorsal setae. The eggs are laid in clusters at the base of the feathers. Turkeys, ducks, and guinea-fowl running with fowls may also be infested with the shaft louse.

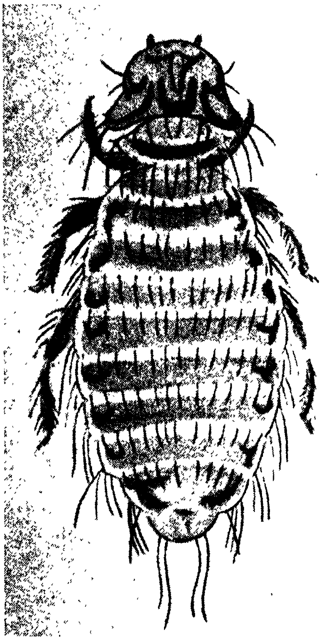

Fig. 60. The shaft louse of the fowl, *Menopon gallinae*
(*After Helmsing.*)

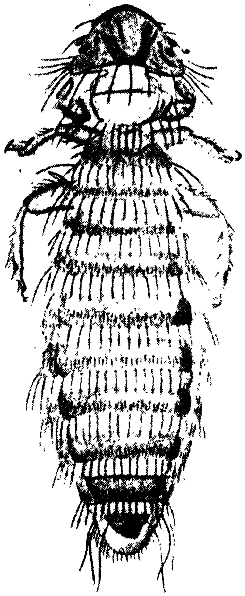

Fig. 61. The body louse of the fowl, *Eomenacanthus stramineus.*
(*After Helmsing.*)

The Body Louse (*Eomenacanthus stramineus* **Nitzsch**—Fig. 61). The body louse occurs on the skin, especially where the body is not densely feathered—for example, on the area below the vent. This is a pale-yellow species about 3·5 millimetres long. The head is somewhat triangular in shape, being very broad posteriorly, and the abdominal segments each possess two rows of setae.

The eggs are laid in clusters on the feathers and near the skin, particularly just below the vent or, in the case of young birds, on the head and along the throat. The egg possesses characteristic filaments on the anterior half of the shell, and hatches in about a week, the young lice becoming mature 17 to 30 days later.

The body louse may also be found on the turkey.

Lice Infesting the Turkey

The Slender Turkey Louse (*Lipeurus gallipavonis* Geoffrey). This is an elongate, slender species up to 3·5 millimetres in length, most frequently seen among the wing feathers. The body is pale yellow with a black margin, and all the abdominal segments except the last are marked with a grey-brown spot on each side.

The Large Turkey Louse (*Goniodes meleagridis* (Linn.)—Fig. 62). This louse can be readily recognized by the strongly angulate temples that extend posteriorly into strong bristles. The thorax is angular with a dark margin, and the abdomen has dark, transverse, interrupted bands. It is a very common louse, infesting the body feathers, particularly of the breast and neck.

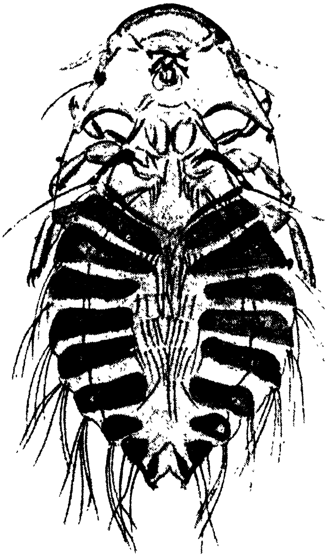

Fig. 62. The turkey louse, *Goniodes meleagridis.*

(*After Helmsing.*)

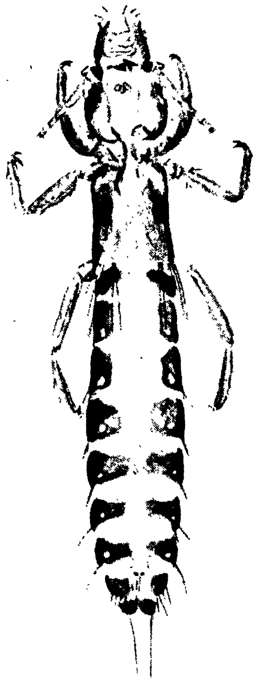

Fig. 63. The wing louse of the duck, *Esthiopterum crassicorne.*

(*After Helmsing.*)

Where turkeys are run with fowls, infestations with the fowl-lice *M. gallinae*, *E. stramineus*, and *L. heterographus* are not uncommon.

Lice Infesting the Duck and Goose

The Wing Louse of the Goose (*Esthiopterum anseris* **(Linn.)**). A slender species 3 millimetres in length, this louse infests the flight feathers. The forehead is very long, its sides being almost straight. The first segment of the male antenna is swollen and the third segment has a lateral process.

The Wing Louse of the Duck (*E. crassicorne* **(Scopoli)**—Fig. 63). This is also a slender species infesting the flight feathers. The head and thorax have a narrow dark border, and the abdominal segments have dark lateral markings.

Anatoecus dentatus **(Scopoli)** (Fig. 64). This is a common louse of the duck, occurring mainly in the region of the head and neck. It is a small, stout species, 1·5 millimetre in length, readily recognized by the clypeal region of the head, which is expanded with an outer, hyaline, free margin. The abdomen has dark lateral markings.

Trinotum anserinum **(Fabr.)**. The thorax is strongly developed and chitinized, the three segments being distinct. The legs are short, stout,

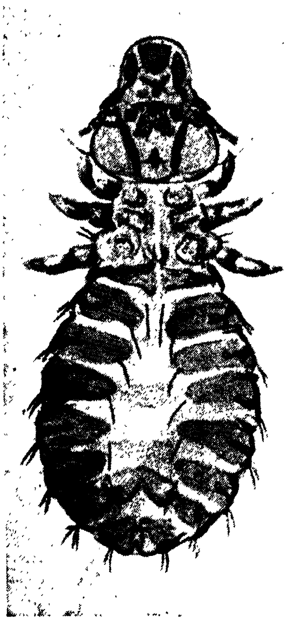

Fig. 64. The duck louse, *Anatoecus dentatus.*

(*After Helmsing.*)

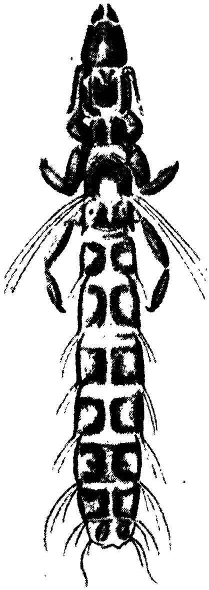

Fig. 65. The pigeon wing louse, *Columbicola columbae.*

(*After Helmsing.*)

and heavy. The species measures up to 6 millimetres and is found on the goose and swan.

T. querquedulae (Linn.). This louse is about 4·5 millimetres long and is found on the duck. The immature forms have large lateral expansions on the thorax, resembling enormous eyes.

The fowl lice, *M. gallinae*, *E. stramineus*, and *L. heterographus*, may also attack ducks that are in contact with fowls.

Lice Infesting the Pigeon

Six species of lice are recorded from the domestic pigeon in Australia, namely, *Colpocephalum turbinatum* Denny, *Columbicola columbae* (Linn.), *Goniodes aegypticus* (Kellog and Paine), *G. damicornis* Nitzsch, *Goniocotes bidentatus* (Scopoli), and *Menopon gigantium* Denny.

The Pigeon Wing Louse (*C. columbae* (Linn.)—Fig. 65). This species is 3 millimetres long and is the most slender of all biting lice, occurring mainly on the flight feathers. The body has a narrow, dark margin and the abdomen is ornamented with large, dark, lateral areas.

G. damicornis (Nitzsch). This is a brown species, with a broad, oval head, angulate temples, and a short, broad abdomen.

The fowl body louse, *E. stramineus*, may also attack pigeons.

Importance of Poultry Lice

It is difficult to assess the economic importance of lice, but it seems probable that the species that infest and feed on the feathers are of little significance, whereas the species occurring on the skin may cause serious ill-effects. The body louse, *E. stramineus*, is undoubtedly an injurious species on grown fowls. Heavy infestations cause a marked reddening of the skin, which eventually becomes scabby and covered with dried blood. This louse is considered to feed on scales and skin secretions, but, since blood can be found in its alimentary canal, it has been suggested that this may not be entirely accidental. The head louse, *L. heterographus*, is frequently recorded as being harmful and even fatal to young chicks and turkey poults, though observations in Canada do not support this view. *M. gallinae* is another species claimed to be harmful to young fowls. As a general rule, heavy infestations of lice are associated with a bedraggled appearance and other symptoms of loss in vitality, though some observers claim that these may be a result and not a cause of the bird's condition.

Heavy infestations are rarely seen on ducks, geese, and pigeons, and it would appear that lice do little harm to these birds.

Control of Poultry Lice

Several insecticides are known that give effective control. These may be applied by dusting, by dipping, or by fumigation.

Dusts. Sodium fluoride, sodium fluosilicate, DDT, BHC, pyrethrum, derris, and chlordane have all been recommended as dusts to control poultry lice. DDT (5 per cent) and BHC (0·5 to 1 per cent gamma isomer) dusts do not appear to have any advantage over sodium fluoride or sodium fluosilicate in killing lice, and do not give any greater residual protection. Chlordane has been very effective at a concentration of 2·5 per cent, but further work with this insecticide is required. Sodium fluoride and sodium fluosilicate are more effective than derris (10 per cent) or pyrethrum (10 per cent). These powders are applied in pinches to the base of the feathers in the region of the head, neck, breast, back, vent, tail, thighs, and wings. They may also be diluted with an inert dust, such as talc (one part of powder to four parts of talc), and applied by means of a shaker.

Dips. Sodium fluoride and sodium fluosilicate are also used as dips at the rate of 1 ounce per gallon of water. A 1 per cent aqueous suspension of sulphur with 0·3 per cent soap, and a derris suspension, 4 ounces of derris per gallon of water, are also effective.

Only warm sunny days should be selected for dipping, and the operation should be timed so that the birds are dry before nightfall. The dipping fluid should be tepid. The fowls are held in one hand by the wings over the back and lowered into the dip, the feathers being ruffled with the other hand to obtain penetration of the fluid. The head is immersed and, after some seconds for drainage, the bird is released.

A DDT dip would kill all lice and give sufficient residual protection to permit eradication. The paragraphs concerning the use of this insecticide for the control of the poultry stickfast flea (p. 65) should be consulted.

Fumigation. This method relies on the use of a volatile insecticide applied to the perches. When the birds roost, the heat of the body causes vaporization of the insecticide, the fumes percolating through the feathers and killing the lice. Fumigation has a very definite advantage over other methods of treatment, for it avoids any disturbance to the birds, such as would be required for treatment by dusts or dipping.

Nicotine sulphate (40 per cent nicotine) can be applied in this manner, and during warm weather will give good control against all species except head lice. It is painted on the upper side of the perches just before the birds go to roost, at the rate of half a pound of nicotine sulphate to every 100 feet of perch. Treatment should be continued for two or three nights, and then repeated after an interval of 9 to 10 days. Care must be given to secure correct ventilation of the poultry-house, so that the birds are not harmed by the fumes, whilst at the same time the fumes must not be disseminated too rapidly to be effective against the lice.

BHC has also been tried as a fumigant, and preliminary trials with concentrations of 0·55 per cent and 1·3 per cent gamma isomer, applied to the perches either as an oily solution or as an emulsion, have resulted in excellent control. The possibility of egg and carcass taint from BHC should be kept in mind.

Fumigation has little effect on head lice (*L. heterographus*) populations.

Sandflies

The term sandflies is commonly used in Australia to denote small biting flies of the families Ceratopogonidae and Simuliidae.

In North America biting flies of the Ceratopogonidae are called no-see-ums or punkies, whilst the term black-fly is used for the Simuliidae. In the Mediterranean region, India, and elsewhere "sandfly" refers to species of *Phlebotomus.*

Phlebotomus Spp.

The minute delicate flies of the genus *Phlebotomus* (Fig. 66 (*d*)) lay their eggs (Fig. 66 (*a*)) in dark and damp situations. The fully-grown larva is only 2 millimetres in length and has very long caudal bristles (Fig. 66 (*b*)).

Very little is known of the Australian species. Three species and one variety have been recorded, but beyond the fact that one species is found breeding in rubble pits, nothing is known of their bionomics. Fig. 66 is an undescribed species that feeds on cattle.

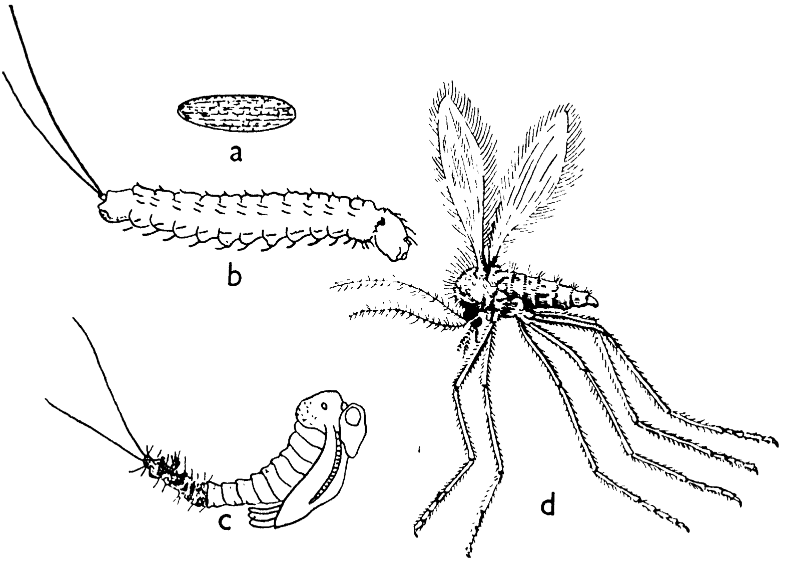

Fig. 66. The life cycle of *Phlebotomus.* (*a*) Eggs; (*b*) larva; (*c*) pupa; (*d*) adult. (*Figs.* (*a*), (*b*), (*c*) *after Roy; Fig.* (*d*) *after Helmsing.*)

In the Middle East *P. papatasi* is the vector of sandfly fever in man. *P. verrucarum* transmits bartonellosis or *Verruga peruviana* of man in Peru. Species of *Phlebotomus* are also incriminated as vectors of leishmaniasis (kala-azar (*Leishmania donovani*) and oriental sore (*L. tropica*)) of man and dogs in the Mediterranean region, near east, southern Russia, the Sudan, India, China, and parts of South America. The Central and South American form of leishmaniasis (*L. brasiliensis*) is also carried by the dog.

Control. Species entering dwellings can be controlled by spraying the walls, ceiling, and screens with a 5 per cent preparation of DDT. The breeding places are treated with DDT or BHC.

Ceratopogonidae

Habits and Life History. Only the females of the Ceratopogonidae bite, some species being confined to animals, whilst others attack insects such as midges, mosquitoes, dragon-flies, beetles, butterflies, and moths. When attacking warm-blooded animals, certain parts of the body may be favoured, such as the legs, the abdomen, and the face, especially the margins of the ears and eyelids. The flies are known to bite at almost any period of the day, though under certain conditions, they may be more numerous in the early morning and late afternoon.

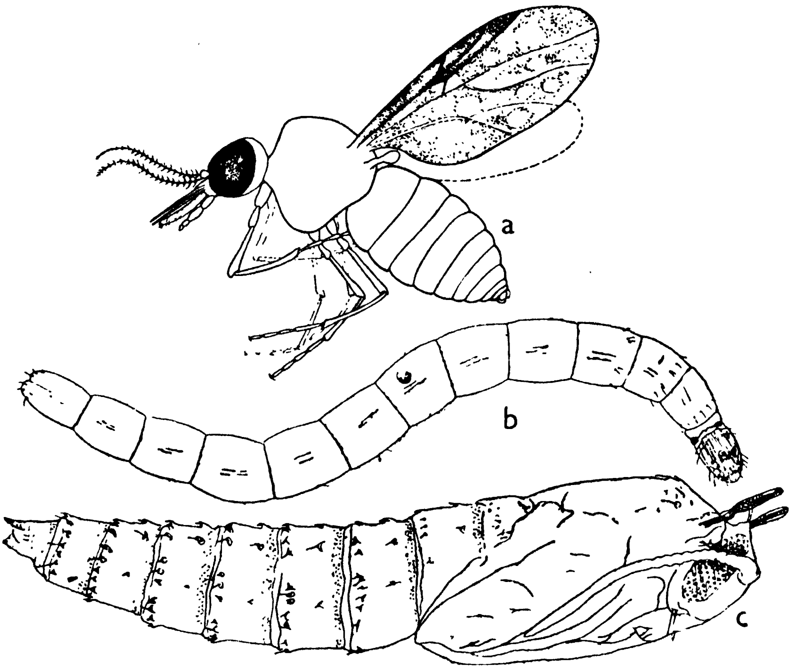

Fig. 67. The life cycle of a ceratopogonid fly. (*a*) Adult; (*b*) fully grown larva; (*c*) pupa.

(*Fig.* (*a*) *after Roy; Figs* (*b*), (*c*) *after Hill.*)

The eggs are usually laid in masses, rarely singly, and the breeding places include wet sand, mud, pools and streams, rot-holes in trees, moist decaying vegetation, manure heaps, and under the bark of trees. Certain species breed in the sand and mud of the seashore. The minute worm-like larva has a distinct head and twelve trunk segments (Fig. 67 (*b*)). It breathes by means of tracheal gills on the posterior segment, which can be protuded or withdrawn, and feeds on minute particles of debris and microscopic animal life. The pupa is amall and delicate, and is inactive except for squirming movements of the abdomen (Fig. 67 (*c*)). Respiratory trumpets are present on the thorax, and attached to the last abdominal segment are a pair of fleshy processes for anchoring purposes. The life cycle, egg to adult, may occupy a period of 4 to 7 months, depending on the prevailing temperatures and presence and amount of moisture (Fig. 67).

Importance. In all parts of the world where these small flies occur, they are known to be persistent and irritating pests of man and animals. The bite is frequently painless, but is usually followed by intense irritation some hours later. Several species are known vectors of helminth parasites. *Acanthocheilonema perstans* of man is carried by *Culicoides austeni* and *C. grahami* in Africa, and *Mansonella ozzardi* by *C. furens* in the West Indies. *Onchocerca cervicalis* of the horse uses *C. nebeculosus* as its vector in England, whilst in Malaya species of *Culicoides* are recorded as intermediate hosts of *O. gibsoni*, the cause of worm nodules in cattle. Species of this sandfly genus spread blue-tongue of sheep in South Africa, where they have also been incriminated as vectors of horse-sickness.

Whilst the systematics of the Australian species have recently been given considerable attention, very little is known of their association with livestock. They are widely scattered throughout the continent, but appear most prevalent along the coast. Great numbers are frequently encountered in the vicinity of small streams and lakes. The densest populations are found on the sea-coast, particularly in mangrove swamps and during warm periods of the year following high tides. Cattle and horses in these areas are readily attacked, particularly on the ears, and appear to suffer severe irritation. The species mainly concerned belong to the genus *Culicoides*. In addition to these, species of *Lasiohelea*, *Atrichopogon*, and *Forcipomyia* are known to attack cattle and horses.

The parasitic roundworms *O. gibsoni* of cattle and *O. cervicalis* of horses are widespread in Australia, the former being of major economic importance. The vectors of these helminths are unknown in this country, but the observations recorded overseas strongly suggest that these are species of Ceratopogonidae that feed on these animals and have a distribution in keeping with that of the parasites. These small flies have been suggested as vectors of ephemeral fever of cattle in Australia. They have also been reported as the cause of Queensland itch of horses, a skin disease resulting from a hypersensitivity to their bites.

Control. Salt-marsh species have been successfully controlled in the United States by the use of dykes and tide-gates, whereby flooding of large areas is prevented and surface-draining is facilitated.

Promising results have followed the use of DDT sprayed from aircraft or discharged as an aerosol from fog generators mounted on trucks or boats.

Where breeding is confined to small areas it may be controlled by spraying BHC in a miscible oil at the rate of 100 milligram of 0.01 per cent gamma isomer per square foot.

Whilst repellents such as dimethyl-phthalate, Indalone, and Rutgers 612 are effective for several hours, their use with large numbers of animals may not be practicable. A spray of 1 to 2 per cent DDT is promising, but has yet to be critically tested. Smudge fires are an old and well-tested method of protection.

Simuliidae

Habits and Life History. The Simuliidae (Fig. 68 (*a*)) are small flies, chiefly diurnal in habit, and only the females bite and suck blood. As a rule they do not travel very far from their breeding places, but swarming and migration occur in the case of at least one species, *Simulium columbaczense* (Schiner), which breeds in the Danube basin in Europe.

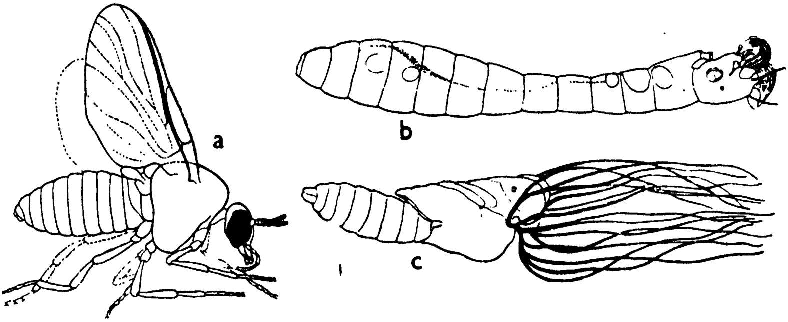

Fig. 68. The life cycle of a simuliid fly. (*a*) Adult; (*b*) fully grown larva; (*c*) pupa. (*Fig.* (*a*) *after Gibbons; Figs* (*b*), (*c*) *after Castellani and Chalmers.*)

Some species will feed only on the lower warm-blooded animals, and will not attack man. Others utilize birds, cold-blooded animals, or even other insects as hosts.

Members of this family breed only in running water. The eggs are deposited in masses on submerged or sometimes on partly submerged objects that are lapped by water. The larvae (Fig. 68 (*b*)) are gregarious and cling tightly to rocks, sticks, etc., beneath the water. For this purpose the posterior end is provided with concentric circles of minute hooks, which fasten to glutinous threads secreted from the mouth of the larvae on the selected spot. At the anterior end is a pair of mouth-fans, which sweep minute organisms and particles of organic matter into the mouth. On the ventral surface of the first thoracic segment is a small leg-like protruberance crowned with hooks. With this, and assisted by the posterior holdfast organ, the larva is enabled to change its position. It breathes by means of blood gills situated in the rectum and capable of protusion and contraction. When fully grown the larva pupates in a cocoon spun from the salivary gland. This cocoon is shaped somewhat like a slipper or wall pocket and is attached to a submerged object. Its upper end is open and through this the pupa protrudes its gill filaments (Fig. 68 (*c*)). The adults escape through a slit in the cocoon and are carried to the surface on a bubble of air collected during the transformation period. The life cycle, egg to egg, may be completed in warm countries in six weeks or less.

Importance. The bite of these insects is severe, and the subsequent irritation and swelling denotes the injection of some poisonous material. Animals will tolerate these pests to a conspicuously lesser extent than other small biting flies such as mosquitoes. Attacks usually drive animals frantic and, if the fly-wave is prolonged, mortalities may occur. These are chiefly from exhaustion, but, no doubt, the inoculation of some poisonous secretion by the flies also assists. Any part of the body may be attacked, but the flies usually prefer the legs, abdomen, ears, and face, particularly round the eyes and in the nose and ears. In fact, so thickly may they occur in the nasal cavities that the inhalation of flies into the lungs may have fatal results.

All classes of livestock suffer. Poultry appear particularly susceptible, and among cattle even a short fly-wave may result in a conspicuous loss of condition and a decreased milk yield. *S. columbaczense* was responsible for the deaths of nearly 17,000 cattle, horses, pigs, sheep, and goats in 1923 in south-west Rumania.

Some species are also vectors of serious diseases. In the United States malaria of ducks (*Leucocytozoon anatis*) and of turkeys (*L. smithi*) is transmitted by *S. venustum* and *S. occidentale* respectively. The intermediate host in England of *Onchocerca gutturosa*, a roundworm parasite of cattle that is widely distributed in Australia, is *S. ornatum*. An allied worm parasite of man, *O. volvulus*, is carried by *S. damnosum* and *S. naevei* in Africa and *S. ochraceum* and others in Central America. Black-flies will also carry the virus of myxomatosis of rabbits.

Important Australian Species of Sandflies

Twenty species of sandflies have been recorded from Australia. Very little is known of the habits of the adult forms, and only two species have been recorded as attacking stock, namely *Austrosimulium bancrofti* Taylor, and the Dawson River sandfly, *A. pestilens* Mackerras and Mackerras.

Austrosimulium bancrofti. The role of this species as a pest of livestock is not very clear. It is recorded from Queensland, New South Wales, South Australia, and Western Australia. It has been taken from cattle and horses in Queensland but only in small numbers, and in Western Australia it is reported to attack horses viciously during the spring and summer in the Darling Ranges.

The early stages occur in strongly flowing water, usually opalescent, but sometimes clear or muddy, where they are attached to any submerged object, preferably limbs and logs. The larvae crowd together in dense masses and may be found to a depth of at least 15 inches. The pupae occur in cracks and crevices somewhat sheltered from the direct force of the water (Fig. 69).

The Dawson River Sandfly (*A. pestilens*). This is the pest species so well known in Queensland. Present records are confined to that State, where it is widely distributed west of the Dividing Range to the New South Wales border. East of the Divide it is a pest in the Dawson Valley.

It is known to attack man, cattle, horses, sheep, dogs, and kangaroos and wallabies very readily, showing little preference for any one species of host.

Habits and Life History. The larvae and pupae are found only when the rivers and creeks in these areas are in flood from the summer rains, and very muddy. They are seen in dense masses on sticks, stumps, and logs, but mainly on the submerged branches and leaves of living trees growing in the beds and along the banks of the flooded streams. These are mainly tea-trees, of which *Melaleuca branchiata* is the most common. When the floods recede, the larvae and pupae disappear, but they are seen when the streams flood again (Fig. 70).

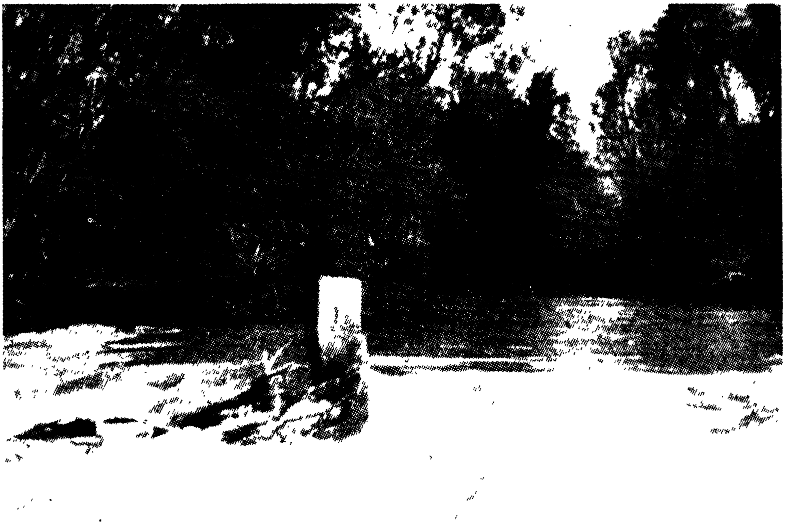

Fig. 69. Breeding ground of *Austrosimulium bancrofti*.
(*After Mackerras and Mackerras.*)

In many parts of the State where this insect reaches pest proportions, the rivers cease to flow during the dry season and are represented by a series of waterholes. Some resistant stage is necessary to carry the species over during the adverse months until conditions become favourable for breeding once more. This resistant stage is unknown, but it is probably the egg.

The adults are closely associated with the trees growing along the stream banks, where they shelter after emerging and feeding. However, they have been reported 10 to 12 miles distant from their breeding grounds. They appear in immense numbers about 10 days after the flood comes down, and the wave lasts 10 to 14 days. There may be several waves during the rainy season when further flooding occurs.

Importance. During a sandfly-wave cattle are driven from water and spend the daylight hours milling about in mobs, raising dust that gives them some protection. Sheep react in a similar manner. Calves and lambs become separated from their mothers during a sandfly-wave, and mortalities among lambs, particularly, may be high. Separation from the ewes is no doubt responsible to some extent for losses amongst the lambs, but the thick masses of flies that crowd round their eyes and inside their ears and nostrils must also play a considerable part. In severe fly-waves deaths among kangaroos have often been reported.

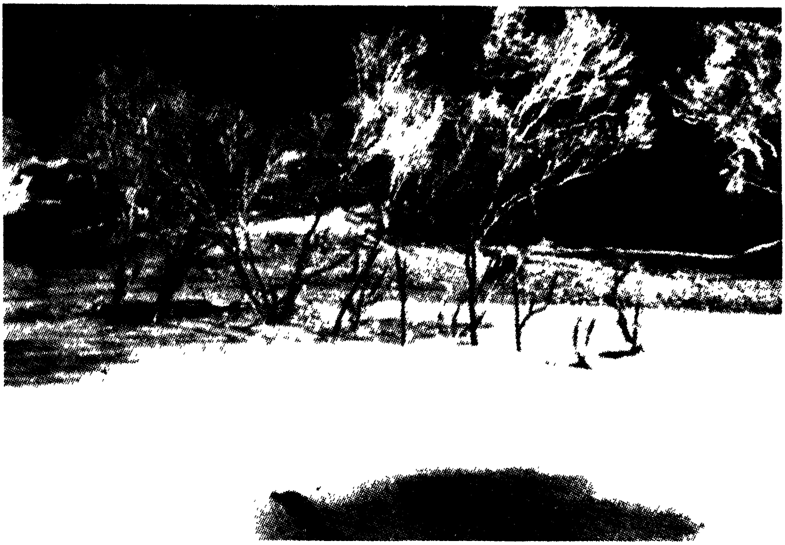

Fig. 70. A former breeding ground of *Austrosimulium pestilens.* Empty pupal cases are thickly distributed over the tea-trees growing in the stream.

(After Mackerras and Mackerras.

Control. Before the advent of DDT as an insecticide to control these pests, recommendations were limited to (*a*) interference with the streams to render them unsuitable for breeding, such as damming to reduce the rate of flow of the water, and removing all objects from the stream to which the larvae could attach; (*b*) using heavy miscible oils such as phinotas oil, which is lethal to the larvae in high dilutions; and (*c*) application of repellents.

Both larvae and adults are very susceptible to DDT. In trials carried out in Guatemala in fast-flowing mountain streams, emulsions or suspensions added to a stream in sufficient quantity to provide a concentration of 1 in 10,000,000 at the point of application have been found to eradicate the larvae for a distance up to 6 miles downstream.

Simulium naevei, a vector of *Onchocerca volvulus*, was eradicated from an area of 65 square miles in southern Kenya by using concentrations of 5 parts per 1,000,000 applied for 30 minutes daily for periods of 10 to 30 days. In the Kenya trials, drip-cans were used with one or more holes in the bottom to give a standard rate of delivery, but during observations in Guatemala it was considered that a better method of application of the DDT would follow from the use of absorbent solids, such as sawdust.

DDT has also been used successfully in northern Canada and Alaska. Chlordane and toxaphene have also given promising results.

Adults may be effectively dealt with by DDT sprays from aircraft or by aerosols from ground equipment, using the same concentrations as for mosquito-control. No doubt, also, considerable control would be obtained by dipping or spraying all stock with a DDT preparation, a 1 to 2 per cent concentration being suggested.

Under Queensland conditions DDT treatment to kill the larvae does not appear practicable, owing to the width of the streams when flooding occurs. A more feasible line of attack would take into consideration the immense number of newly emerged and fed flies that shelter in the trees along the stream banks, and that could be destroyed by spraying from aircraft or by aerosols released from fog-generator equipment mounted on trucks. Where dips are installed for the control of cattle tick, dipping in 0·5 per cent DDT would probably give considerable relief. Repellents such as dimethylphthalate, Rutgers 612, and Indalone will afford appreciable protection to man. Smudge fires will provide relief to stock, for the flies are very sensitive to smoke. Animals are readily attracted to smudge fires, and in this connection DDT and BHC smokes may be worthy of consideration.

Mosquitoes

Habits and Life History. The great majority of mosquitoes live on blood. Only the females suck blood, and the males live on plant juices. In some species both males and females obtain their food from plants. Some mosquitoes are active only during the day, often being most vicious in the early morning and late afternoon. Others suck their blood meals only at night. There are, however, a number of species that are active at any time during the day and night. Some are domestic in habit, occurring only in the vicinity of habitations; others are loath to enter houses and stables even to feed. The adults are rarely found very far from their breeding places, although in the case of the salt-marsh species, migrations of 80 miles or more from the breeding grounds are not uncommon.

Mosquitoes, as a rule, display little host preference and will feed on any warm-blooded animal. Some even extend their host range to cold-blooded animals. There are, however, a few mosquitoes that confine their attacks to the lower animals and do not bite man.

A wide variety of breeding places is known, but each species shows a distinct preference for certain types of breeding places. Some utilize salt or brackish water, others fresh water, which, according to the species, may be in ponds, streams, marshes, small puddles, or rot-holes in trees, and in artificial containers such as tins, jugs, etc. Sunlight frequently plays a part in the selection of a breeding place, though the factors governing this selection are little understood.

Development of the eggs and oviposition are typically dependent on the ingestion of a blood meal. The eggs are usually deposited on the surface of the water. In some species they may be attached to partly submerged objects, or they may sink to the bottom. In others the eggs are laid in dry places that are subject to flooding. Under suitable conditions the eggs hatch in a few days (Fig. 21).

The larva or "wriggler" grows rapidly and feeds on vegetation, or may be predacious or even cannibalistic. It has a distinct head and thorax and is provided with long hairs,which assist it in swimming. The head is furnished with a mouth-brush of stiff hairs, which sweep minute objects into the mouth (Fig. 21). In the predacious species these hairs are specialized into processes for holding the prey. The larvae breathe air, for which purpose the posterior end is provided with a breathing siphon. The surface film of the water is pierced with this siphon and air is drawn into the trachea. Sometimes the breathing siphon is specially adapted for piercing the stems of aquatic plants, from which the larvae obtain air. Tracheal or caudal gills are present on the last segment. These extract chlorides from the water, which are essential for the nutritional requirements of the larva. There are four moults to pupation, and under favourable conditions the larva may be fully grown in one to two weeks.

The pupa is comma-shaped, with a large head and thorax and a flexible abdomen (Fig. 21). This stage is active and usually lies at the surface of the water. It breathes by means of a pair of breathing trumpets attached to the dorsum of the thorax. The pupal stage lasts only a few days. The adult emerges through a slit in the thorax and rests for a short time on the old pupal skin to dry its wings before taking flight.

Importance. When numerous, mosquitoes can be a source of extreme worry and annoyance to domestic animals and birds. Their attack may be sufficiently severe to cause marked loss of condition, a decreased milk-yield, and even death. These effects are caused mainly by the irritation from the bites. Loss of blood may be important, for it has been estimated that for every 500 mosquitoes feeding there is a daily loss of 24 millilitres of blood.

The role of mosquitoes as vectors of disease is notorious. Encephalomyelitis of horses in the United States is transmitted by a number of species belonging to the genera *Aedes* and *Culex*, *C. tarsalis* being probably the most important natural vector. Equine infectious anaemia is probably mosquito-borne. Rift Valley fever of sheep and man in British East Africa is spread by *A. durbanensis*, *Eretmapolides* spp. and *Mansonia* spp., while blue-tongue of sheep in South Africa has *Aedes lineatopennis* as one of its vectors. Fowl-pox, a virus disease of chickens, is disseminated by a variety of species belonging to the genera *Aedes*, *Culex*, *Anopheles*, and *Theobaldia*, whilst species of *Psorophora* have been incriminated as mechanical vectors of anaplasmosis (*Anaplasma marginale*) of cattle in the United States. Poultry malaria (*Plasmodium gallinaceum*) is mosquito-borne. Certain species of *Anopheles*, *Aedes*, and *Culex* are also intermediate hosts of *Dirofilaria immitis*, the heart-worm of dogs, the species chiefly concerned being *Aedes aegypti* and *C. fatigans*. *A. aegypti* and *C. annulirostris* and probably other species carry rabbit myxomatosis.

Malaria, dengue fever, yellow fever, and filariasis of man are also carried by mosquitoes. The vectors of malaria are confined to the genus *Anopheles*, of which a number of species are implicated in the various countries in which this disease occurs. The principal vector of yellow fever in settled areas, urban or epidemic yellow fever, is *Aedes aegypti*, whilst jungle yellow fever or endemic yellow fever, as known in South America and Africa, may be transmitted by many species belonging to a number of genera, *Haemagogus spegazzinii* and *A. africanus* being the most important natural vectors.

Dengue fever is carried by *A. aegypti*, *A. albopictus*, *A. scutellaris* and *Amigeres abturbans*. Filiariasis, due to the roundworm *Wauchereria bancrofti*, which may complete its development in a large number of species of mosquitoes, is transmitted in many countries by *C. fatigans*, whilst *C. pipiens*, *Anopheles punctulatus*, and *Aedes variegatus* are also known vectors in Egypt, New Guinea and the Celebes, and the East Indies and Fiji, respectively. Another filariid worm, *Microfilaria malayi*, uses. species of *Mansonia* as intermediate hosts. In tropical America certain mosquitoes, principally those belonging to the genus *Psorophora*, are utilized by the myiasis fly, *Dermatobia hominis*, as vehicles for its eggs.

Important Australian Species of Mosquitoes

***Anopheles punctulatus*.** On the Australian mainland the variety of mosquito known as *A. punctulatus farauti* Swellengrebel and Swellengrebel de Graff is the most important vector of malaria. In New Guinea and the Solomon Islands it shares this role with *A. punctulatus punctulatus* Donitz. Both races are also vectors of human filariasis. The relationship between anophelines and livestock in Australia is not very clear. *A. punctulatus farauti* will feed on all domestic animals and poultry. It is confined to northern Australia and may at times reach pest proportions. It is also a possible vector of *Dirofilaria immitis*, the heart-worm of dogs, which is extremely prevalent in the northern part of the continent. Other species known to feed on domestic animals are *A. annulipes*, *A. bancrofti bancrofti*, and *A. amictus amictus*.

***Culex fatigans* Wied.** (Fig. 71 (*b*)). This is a night-biting species found in the Ethiopian, Oriental, and Australasian regions. It is a medium-sized mosquito with pale-golden scales on the thorax. This is marked with dark stripes, which are best seen on rubbed specimens. The abdomen has pale creamy bands and sometimes pale lateral spots. The legs are brown, the bases of the femora, the knees, and frequently the apexes of the tibiae are pale. The proboscis is unbanded.

The species breeds in polluted water, such as sewerage-contaminated water, septic tanks, drainage from bathrooms, and liquid manure, and is principally a house-frequenting species. It transmits filariasis of man and heart-worm of dogs.

***C. annulirostris* Skuse.** A widespread, medium-sized mosquito, this species has a white-banded proboscis, and bands of creamy scales on the abdomen, the bands being broadly triangular in shape. It breeds in accumulations of fresh water containing an abundance of vegetation. It is disinclined to enter dwellings, but is a vicious biter outdoors, particularly at dusk. This mosquito is an important vector of the virus of rabbit myxomatosis.

Aedes aegypti **(Linn.)** (Fig. 71 (*a*)). The tiger mosquito is also a house-frequenting species. It is small and dark, ornamented with silver scales arranged in lines and spots. The head has a medium double band of white scales, whilst the palpi have two basal white bands in the male and are tipped with white or are entirely white in the female. The thorax has a white lyre-shaped ornamentation and the scutellum is white. The abdomen is white-banded, and the legs have white knees and broad white bands on the tarsi. The proboscis is unbanded.

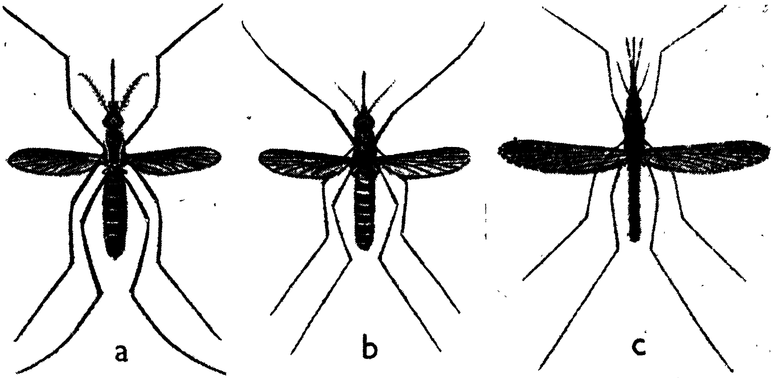

Fig. 71. (*a*) *Aedes aegypti*, female; (*b*) *Culex fatigans*, female; (*c*) *Anopheles annulipes*, female. (*After Patton.*)

This species is distributed throughout tropical and subtropical countries. The larvae are found in rainwater tanks and other receptacles holding fresh water about dwelling houses.

In Australia *A. aegypti* is responsible for dengue fever epidemics in man and will also transmit heart-worm in dogs. It bites chiefly during the day.

A. vigilax **Skuse.** This species is a vicious biter and is a well-known salt-marsh or mangrove mosquito. It is a small dark mosquito with white-banded legs and abdomen and with the proboscis brownish beneath for about half its length. It breeds mainly in the brackish swamps along the coast, particularly where mangroves grow. The adults in these areas occur in countless millions and may be active at any time of the day and night, but more so at dusk and dawn. They do not readily enter houses.

This mosquito is considered capable of migration, for adults have been found, sometimes in numbers, at distances of 80 or more miles inland from their breeding grounds. The species is not known to carry any disease among livestock, but is a vicious pest in the coastal areas.

A. vittiger **Skuse.** This is a large brownish species with dark stripes on a creamy thorax, and banded legs. It has a wide distribution, but reaches its highest development in inland areas, where, during the rainy season, it can make life miserable for both man and beast. It breeds in clear or muddy waterholes, but nothing is known of its biology in the western areas, particularly during the dry season.

Mucidus alternans **Westwood.** One of the largest mosquitoes known, the Scotch Grey or Hexham Grey is a black and grey speckled species with breeding habits similar to those of *A. vigilax*. It is of interest solely because of its size, for it is rarely seen in large enough numbers to be a pest, and is not known to carry any disease.

Mansonia uniformis **Theo.** This is another pest species, with a wide distribution in Australia, occurring also in Ethiopian and Oriental regions. It is a medium-sized mosquito with a black-tipped proboscis and a thorax covered with large whitish-green, brown, and black scales, arranged more or less in stripes. The abdomen has pale spots laterally and the legs are spotted and banded. The wings are densely covered with large white and black scales along the veins.

The larvae occur in swamps and pools and breathe by piercing certain aquatic plants with a specially modified siphon.

A. theobaldi is a small dark species which frequently reaches pest proportions in the bush.

Control of Mosquitoes. Permanent control can be secured only by the elimination of the breeding grounds by such measures as draining and filling. Effective reduction in numbers, in the case of a few species, has been obtained by altering the conditions of the habitat in such a way as to make it unsuitable to them.

Other control measures give only temporary relief and have to be repeated at regular intervals. These consist of the application of larvicides to the breeding places, and of sprays and residual insecticides to kill the adults. For many years oils sprayed on the surface of the water have been employed against the larvae and pupae, and poison dusts, such as Paris green, have been used to control surface-feeding anopheline larvae. Modern control measures are based mainly on the chlorinated hydrocarbon insecticides some of which are highly toxic in extremely small quantities, both to the immature stages and to adults. DDT for larval control may be used either as a solution in oil or as an emulsion. Dusts are not as effective as these two types of formulations. Mineral oil solutions are highly effective against larvae at the rate of 1 to 2 quarts of 5 per cent or 5 quarts of 1 per cent DDT per acre, equivalent to 0·1 to 0·2 pounds of DDT per acre. Emulsions at the same rate give efficient control against both anopheline and culicine larvae, and are more effective against the latter than solutions. Only the minutest quantity of DDT is required, and although concentrations above those recommended may have to be used under certain circumstances, they should be avoided as far as possible, owing to the susceptibility to DDT of fish and other cold-blooded vertebrates and wild life. Treatment should be repeated at weekly intervals. Dieldrin at the rate of 1 pound per acre is an efficient larvicide, but like DDT will kill fish. BHC emulsion (12 per cent gamma isomer) may be used where there is danger to fish.

For small pools, puddles, etc., the DDT may be applied with a household type of spray gun, or with dropping bottles, a medicine dropper, or a squirt oil-can. For large areas, a knapsack or similar type of spray with small-aperture nozzles to give a slowly delivered mist spray is suitable. For very extensive areas power sprays are best.

Breeding may also be controlled by aerosols or by sprays delivered from aircraft. These methods of application also give excellent adult control. Thermol-generated aerosols at the rate of 15 gallons of 10 per cent DDT per 1000 feet of front has given very promising results, whilst aircraft sprays of 5 to 20 per cent DDT in lubricating oil at the rate of 0·2 to 0·4 pound of DDT per acre are very effective. The larger the area sprayed the longer will be the control at its centre point, for adults from the surrounding untreated areas infiltrate very rapidly.

Sprays developed to control adults in enclosed spaces were formerly pyrethrum, Lethane, or Thanite. Nowadays they usually contain DDT, chlordane, or some other chlorinated hydrocarbon, with which is incorporated certain amounts of pyrethrum, etc., to give a quick knockdown. A mosquito spray developed in Australia during the second world war consists of 0·5 per cent DDT with 0·14 per cent pyrethrins in kerosene. The pyrethrins may be replaced by 2·5 per cent Thanite or Lethane. A spray containing 0·05 to 0·1 per cent pyrethrins and 0·5 to 1·0 per cent piperonyl butoxide is highly efficient. The Freon bomb, designed for space-spraying by the United States during the war, contained 0·4 per cent pyrethrins, 3 per cent DDT, 5 per cent cyclohexanone, and 5 per cent lubricating oil in Freon—12, and gave an aerosol-type spray.

A species of mosquito that rests on the walls of houses, stables, etc., may also be controlled by spraying or painting DDT on the walls at the rate of 1 gallon of 5 per cent DDT for every 1000 square feet. BHC, toxaphene, chlordane and dieldrin applied at a similar rate is also effective, but are not as lasting as DDT.

Dimethyl-phthalate, Indalone, and Rutgers 612 are good repellents, but too costly to use on animals.

It is doubtful whether the wide-scale use of DDT either as aerosols or from aircraft will ever be attempted in Australia simply to protect stock from the bush species of mosquitoes. Stock would benefit, however, where such measures operate to control such pests of man as *Aedes vigilax*, and the bush-fly, *Musca vetustissima.* The treatment of stock by means of hand sprays or dips containing DDT has received very little attention, but in cattle-tick areas, where 0·5 per cent DDT is used in vats or dips to control ticks, it has been observed that promising protection may be expected. In many areas where bush mosquitoes are a pest of cattle and horses, smudge fires are customary and give a respite from attack.

With regard to the domestic species, the screening of rainwater tanks, repairs to rainwater guttering, and the destruction of old tins and other receptacles holding water will go a long way towards controlling *A. aegypti.* Similarly, with *Culex fatigans* attention is necessary to all accumulations of water polluted with manure and household or stable drainage, and to the screening of the outlet pipes of septic tanks. DDT and other chlorinated hydrocarbon insecticides will control larvae breeding in polluted water that cannot be dealt with by drainage or filling, whilst the pyrethrum-DDT sprays will eliminate the adults resting in buildings, particularly in dark corners.

Larvae-eating fish, of which several species occur in Australia, may play their part in mosquito control. One of the best known is an introduced species, *Gambusia affinis*. The introduction of these fish into ornamental ponds and similar restricted areas of water is beneficial.

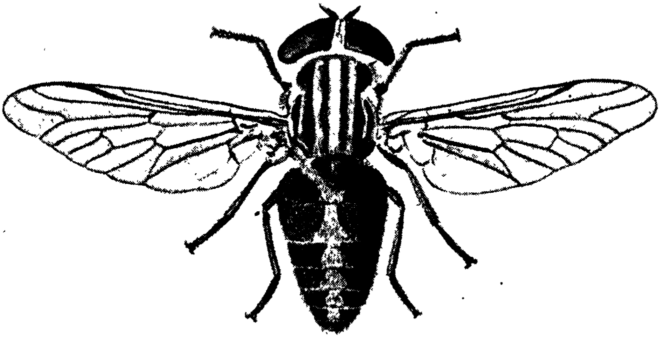

Fig. 72. Tabanus queenslandi.

(After Helmsing.)

March-flies

Habits and Life History. Not all species of tabanids suck blood, and among the blood-sucking species only the female march-flies have this habit. The family is world-wide in its distribution, and its members are found wherever water and damp places are available for breeding purposes. The adults are solitary in habit and may range many miles from their breeding grounds, being most active on warm, sunny days. They are especially abundant in low, swampy districts in tropical and subtropical parts, and feed on a variety of animals and on man, usually favouring the legs and flanks of animals, and the ankles and hands of man.

The eggs which are spindle-shaped, and white, brown, or black in colour are deposited—usually in definitely shaped masses (Fig. 73 (*a*))—on vegetation that overhangs or grows at the edges of marshy spots or water. On hatching, the larvae drop and rapidly disappear into the mud, damp decaying vegetation, or water. They are carnivorous and feed on other insect larvae, small earthworms, and other animal life. The body of the mature larva is usually blotched with coloured bands or stripes and is cylindrical in shape, tapering at both ends. The abdomen bears a circle of three or four pairs of fleshly pseudopods on each of the anterior segments, and has spiracles at the anal end (Fig. 73(*b*)). The mouth-parts are adapted for seizing the prey and sucking its juices, and constitute a formidable apparatus. Pupation takes place in drier soil. The pupa is elongate and cylindrical, and is usually brownish with bands of contiguous setae on each abdominal segment (Fig. 73(*c*)). The skin is finely wrinkled, and the abdomen ends in a large anal tubercle. In warm climates there may be several generations a year, in cold climates usually only one.

Importance. March-flies can be serious pests of livestock, particularly of cattle and horses. Their bite is severe, and a fly may bite several times before repletion. During periods when flies are numerous, animals move about restlessly, breaking into frenzied gallops in attempts to escape from their tormentors. Work that requires horses is interrupted and sometimes has to be carried out at night. Accidents are not uncommon, and cows may become so unmanageable in the milking bails as to seriously lower the milk supply. It has been estimated that large populations of flies may take as much as 100 to 300 millilitres of blood from an animal daily.

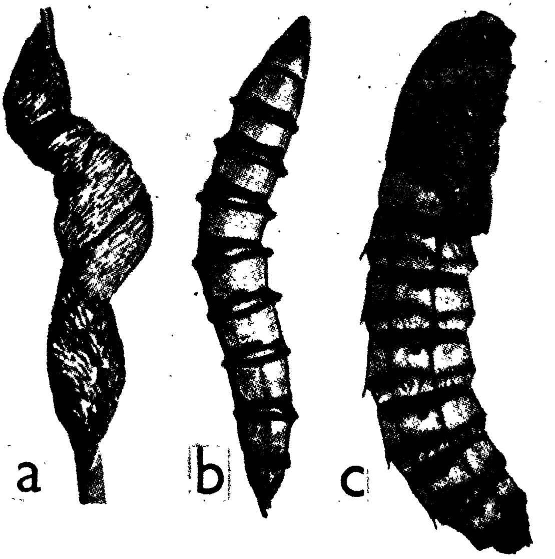

Fig. 73. The life cycle of a tabanid fly. (*a*) Egg mass; (*b*) larva; (*c*) pupa.

(*After Webb and Wells.*)

March-flies are also capable of carrying disease. Their interrupted feeding habits make them mechanical vectors of many trypanosome diseases, such as surra (*Trypanosoma evansi*), mal de caderas (*T. equinum*), murrina (*T. hippicum*), dourine (*T. equiperdum*) of horses, and nagana of cattle and other animals (*T. brucei*). Anthrax may be transmitted in a similar manner, whilst in parts of the United States—for example, in Utah—the deer-fly, *Chrysops discalis*, is an important vector of tularaemia. Anaplasmosis of cattle is also spread in a mechanical manner by march-flies in the United States.

The only known true intermediate hosts among the tabanids are species of *Chrysops*, which, in West Africa, transmit *Loa loa*, a roundworm parasite of man.

Important Australian Species of March-flies

Of the diseases mentioned above, only anthrax and anaplasmosis occur in Australia. The former is a comparatively rare disease and, as yet, march-flies have not been implicated in its epidemiology. Anaplasmosis is normally transmitted by the cattle tick, *Boophilus microplus*, and experimental attempts to transit it with *Tabanus circumdatus* were unsuccessful. It seems that tabanids play little part in the spread of this disease in Australia, for although anaplasmosis has been present in this country for many years, it has not been seen outside the area occupied by the cattle tick.

Although considerable attention has been given to the tabanids in Australia, it has been concerned mainly with their systematics, and very little information exists on the relative importance of the various species that attack livestock. It seems certain, however, that tabanids do not reach pest proportions in Australia such as those reported from areas in Canada, the United States, and Russia. They can, however, be a very serious nuisance during seasons when they are prevalent, making the stock restless and liable to sustain injuries in their attempts to escape attack. Species of *Sylvius* are well-known pests in the warmer tropical areas of the Commonwealth. Species of *Tabanus*, such as the widespread *T. circumdatus* and *T. sanguinarius*, are also prevalent, while *Scaptia violacea* and other species of this genus are common pests of cattle and horses, and cause much alarm even before they bite.

Control. No efficient and practical methods exist for the control of these flies. Their breeding places are usually too extensive to be given adequate attention, and the adults do not appear to be susceptible to DDT to the same extent as other flies. Spraying stock with DDT, for example, seems to exert little, if any, control unless the sprays are applied every 3-4 days. Sprays containing 1·0 per cent. piperonyl butoxide and 0·1 per cent pyrethrins are claimed to protect for 5-6 days. Recommendations from other countries take advantage of the habit of the flies of skimming over pools and touching the under-surface of the abdomen on the water. Oil poured over the surface of the water will kill large numbers of flies.

Body coverings of canvas or hessian will protect stock from attack.

The House-fly (*Musca domestica* Linn.)

The house-fly (Fig. 74 (*b*)) is a common, cosmopolitan species that frequents dwellings, stables, pigsties, etc., and is seldom seen at any great distance from habitations. The male measures up to 6·5 millimetres and has a light to dark-grey thorax with four equally wide, longitudinal, dark stripes. The scutellum has an indistinct, dark, broad median band. The first three segments of the abdomen are yellowish with a black median stripe, which is broadest on the third segment. The fourth segment is diffuse greyish medianly and yellowish laterally (Fig. 75 (*a*)). In the female the ground colour is lighter. The abdomen is lemon-yellow with a dark, central, longitudinal stripe, most pronounced on the anterior segments. There are also a pair of broader, irregular, diffuse dark stripes that converge posteriorly (Fig. 75 (*c*)). The female is 6·5 to 7·5 millimetres in length.

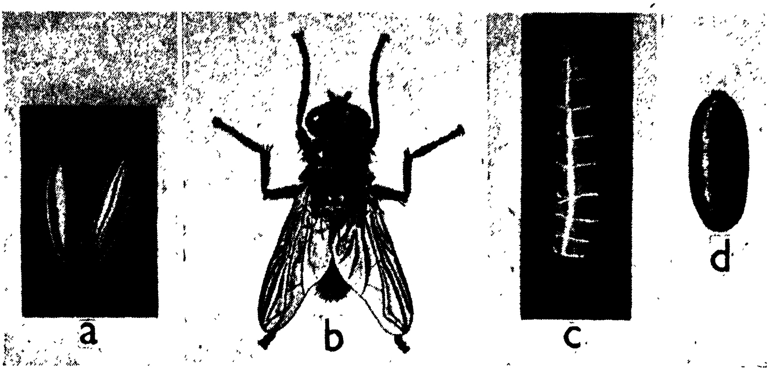

Fig. 74. The life cycle of the common house-fly, *Musca domestica.* (*a*) Egg; (*b*) adult fly; (*c*) larva; (*d*) puparium.

(*After Helmsing.*)

There are a number of species of the genus *Musca* in Australia, but the house-fly can be recognized by (*a*) its yellowish coloration; (*b*) the presence of four distinct and equally broad dark stripes on the thorax; and (*c*) the presence of hairs in front of the anterior spiracle and below the humeral callus.

Habits and Life History. The house-fly feeds upon a wide variety of substances, such as foodstuffs and decaying vegetable and animal matter including excreta. After feeding, a fluid is usually regurgitated from the crop, and this "vomitus" may be used to liquify solid foods. The small spots on ceilings and other places where flies rest are mainly vomit spots. If food-supplies become scarce *M. domestica* may migrate, and it has been known to fly a distance of 6 miles within 24 hours, and to migrate for at least 13 miles. The adult is practically diurnal in habit, and disappears during the winter months.

The female fly may commence oviposition within 2½ days after emergence. The eggs are laid in batches of 120 to 150, and during her lifetime a single female may lay as many as 2400 eggs. These are laid in a wide variety of substances, such as the excreta of various animals, and all kinds of decaying animal and vegetable matter. The flies have been bred also from sheep that have been "struck" on the breech, no doubt being attracted by accumulations of faeces and urine. Horse manure is a favoured medium. The flies are also partial to human, pig, and fowl excreta. The excreta of cattle, on the other hand, is usually not very attractive to them unless it contains straw, chaff, or similar substances.

The eggs, which are deposited in sheltered positions, are 1 millimetre long, elongate, creamy-white, and provided with two rib-like structures on the dorsal surface (Fig. 74(*a*)). Hatching usually takes place within 24 hours—under very favourable conditions it may occur in about 8 hours. The larvae are mature in 4 to 7 days, though in cold weather, or if food is scarce, or if the medium is dry, development may be considerably delayed. The larva (Fig. 74(*c*)) is a typical maggot tapering to the head end and provided at the posterior end with a pair of spiracles, whose structure enables an identification of the species.

Just prior to pupation the larvae crawl about seeking a suitable place in which to pupate. This may take place in the drier parts of the breeding medium, but more usually in the soil beneath and round it (Fig. 74(*d*)). Transformation to the adult is completed in 3 to 6 days in summer, but may take up to 5 months in winter.

The life cycle may be thus completed in 8 to 14 days in summer, and during this season of the year there may be as many as 10 to 12 generations. Provided there is an adequate supply of food the flies may live for 2 to 4 weeks in summer, but considerably longer in cool weather. During the winter the insects hibernate in the immature stages mainly as prepupae, which possess a fair degree of resistance to low temperatures.

Importance. The role of the house-fly as a vector of diseases affecting domestic animals and birds has not received very much attention. It is an intermediate host of the poultry tapeworm, *Choanotaenia infundibulum*, and of the equine stomach worms, *Habronema muscae* and *Draschia megastoma*. The larvae of these worms may also be carried by flies into the eyes and into abrasions on the body, and give rise to habronemic conjunctivitis, and a skin condition known as summer sores, or habronemic granulomata. Swamp cancer of horses may have a similar origin, and blight in cattle is probably transmitted by the house-fly. It may also carry mastitis in cattle, and the eggs of the pig roundworm, *Ascaris lumbricoides*, and of other helminths. No information is available concerning its importance as a vector of other pathogenic micro-organisms present in the excreta of animals in which it breeds, and in the secretions and infections on which it feeds. It seems quite certain, however, that house-flies are as guilty here as they are with such human diseases as tuberculosis, typhoid, dysentery, poliomyelitis, cholera, anthrax, etc., the causal organisms of which may be carried externally on the hairs of the body and on the pulvilli, or may be ingested, to be later excreted or vomited.

Control. The fact that house flies breed so readily in animal excreta, and are vectors of so many human diseases, makes their control an important responsibility of the livestock owner, particularly where horses, pigs, and poultry are concerned.

Prevention of Breeding. This can be accomplished only by the regular and thorough collection of manure and its treatment or disposal so that breeding does not occur. This is assisted by the provision of good flooring in stables, pigsties, etc., to allow of thorough cleansing. Where the manure can be used immediately for agricultural purposes, it is spread very thinly over the pastures or cultivation, when it will quickly dry out and become unattractive to the flies. Where manure is stored, breeding may be prevented in the following ways:

1. By using fly-proof pits or boxes.

2. By making hard compact heaps. This is done by beating down the outer layers with a shovel. The heat generated in such a heap will kill all larvae except those in the outer layers, which therefore are turned into the heap every few days. The heap may be covered with creosote-soaked hessian, or with three inches of hard-packed earth.

3. By chemical treatment of the heap. Orthodichlorobenzene applied to the surface at the rate of 2 to 3 lb. per 100 square feet is very effective. By spraying the heap with DDT, 1 gallon of 1 per cent per 100 square feet, many of the emerging flies are killed. Chlordane, 200 milligrams per sq. ft., technical BHC, 200 milligrams per sq. ft., lindane, 50 milligrams per sq. ft., and dieldrin, 50 milligrams per sq. ft., are considered highly efficient larvicides. Borax, 11 ounces to 8 bushels of manure, is cheap, but must be used with care, for it is dangerous to plant life in any greater quantities, if the manure is used for fertilizing purposes.

4. By storage traps, in which the manure is stored in open compartments over shallow concrete basins filled with a maggot poison. The walls of the basin are fitted with curved metal shields to prevent the larvae from escaping.

Manure is most attractive to flies during the first three to five days. When stored for three weeks or longer it becomes unsuitable for breeding purposes.

Soil contaminated with faeces, urine, and other waste animal matter such as food scraps, also breeds flies. Chemical treatment is usually most practicable. The proper disposal of garbage is also necessary, and this should be stored in fly-proof garbage cans and finally disposed of by burning or deep burial.

Destruction of Adults. Prior to the advent of the chlorinated hydrocarbon insecticides, destruction of adult flies was accomplished by pyrethrum and derris fly-sprays, by poisoning with sodium arsenite or with formalin in sweetened milk, and by trapping, using sticky resin fly-papers and box-type traps with attractive baits.

Adult control now relies mainly on the residual action of such insecticides as DDT, BHC, methoxychlor, chlordane, and toxaphene. Of these, the residual toxicity of DDT is most lasting, and a 5 per cent solution, emulsion, or suspension applied to walls, ceilings, etc., at the rate of 1 gallon per 1000 square feet, will continue to kill flies for many months. When the DDT is exposed to sunshine the residual effect is not as long-lasting as it is when the DDT is in the shade. If treatment is carried out carefully, the effect on the fly population will be obvious within a few days. Treatment is repeated when the flies commence to increase in number again. If used on lime-washed surfaces DDT does not last as long as it does on untreated surfaces. It may also be applied effectively in paints such as flat-oil paints, glossy enamels, and distemper paints, DDT-resistant strains of house-flies have been reported from North America, Italy and elsewhere, and resistance to other chlorinated-hydrocarbon insecticides has also been observed. Flies resistant to DDT can usually be controlled by one or the other allied insecticides such as chlordane, 200 milligrams per sq. ft., dieldrin, 50 milligrams per sq. ft., and lindane, 50 milligrams per sq. ft.

Because DDT is stored in the body, mainly in the fat, and is excreted in the milk of cattle over long periods and in quantities considered by authorities in the United States to constitute a definite risk of causing chronic DDT-poisoning in man, methoxychlor and lindane (gamma BHC) are recommended for fly control in dairy barns and on milking cows. These insecticides are the least toxic of their type to warm-blooded animals, for they are not stored in the body to the same extent as DDT, and furthermore, are eliminated from the body much more rapidly.

The space sprays mentioned on p. 105 with reference to adult mosquito control are also very effective against house-flies. Screening of dwellings and stables is essential wherever house-flies are prevalent.

The Bush-fly (*Musca vetustissima* Walker)

The bush-fly is slightly smaller than *M. domestica*, which it closely resembles. The four dark stripes on the thorax are visible only anteriorly, the two outer pairs thereafter being fused to form two very broad stripes. The first segment of the male abdomen is dark and from it a median stripe extends posteriorly with extensions along the hind borders of the segments (Fig. 75 (*b*)). On the abdomen of the female are additional lateral, oblique bands extending from the anterior to the posterior margins of the segments (Fig. 75 (*d*)). The wings are clear, the curvature of the vein M_1 being greater than in *M. domestica*, the angle approaching more nearly to the hind border of the wing.

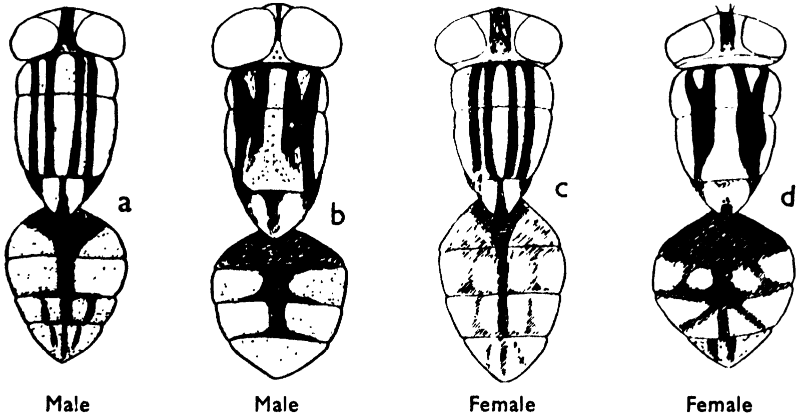

Fig. 75. (*a*), (*c*) Thoracic and abdominal markings of the house-fly, *Musca domestica*; (*b*), (*d*) thoracic and abdominal markings of the bush-fly, *M. vetustissima*.

(*After Johnston and Bancroft.*)

Habits and Life History. Indian records show that a species of the same name is present in that country, though it remains to be confirmed whether this and the species identified in Australia as *M. vetustissima* are identical. The bush-fly is widely distributed throughout Australia, reaching its highest development in inland areas. Even in districts with an annual rainfall as low as 10 inches, it is very abundant.

The bush-fly is most prevalent during the summer and autumn, when the numbers run into millions, particularly in inland districts. It is diurnal in habit, and activity usually ceases at the onset of darkness. It is mainly a bush-fly and does not enter habitations to any extent. On man and on stock, chiefly cattle and horses, it frequents the eyes, mouth, ears, and any wounds, feeding on the secretions and crawling from one feeding position to another. On mares and cows it will also cluster round the vulva. On man, it has the habit of resting in large numbers on the back and hat, being carried for many miles in this manner.

It is known to breed in cattle- and horse-dung, and also in the paunch contents of sheep carcasses. These breeding places, however, do not account for the myriads that infest the country. Indeed, in far inland areas where the stocking rate is comparatively low, the flies are extremely prevalent, even during drought times.

In horse-manure the eggs, which are 1·5 millimetres long, are laid in batches of 20 to 40 just below the surface. In warm weather hatching occurs in 24 hours or less. The maggot grows rapidly and is fully fed in about 5 days, when it measures 10 millimetres. The pupal period is 6 days in summer and 10 to 14 days or more in winter.

Importance. The habit of the bush-fly of feeding on the secretions of the mouth, eyes, ears, and nose, and the countless numbers in which it occurs, makes it an extremely irritating pest to both man and beast (Fig. 76(*c*)). It also clusters round and on wounds and abrasions. In horses particularly, the healthy flesh round wounds, in the corners of the eyes (Fig. 76(*a*)) and mouth, and round the vulva (Fig. 76(*b*)) appears to be eaten away, leaving cavities.

In some cases the animals become so badly affected during the fly season that they have to be destroyed. The bush-fly plays an important part in the formation of skin sores in cattle infested with the buffalo-fly, *Siphona exigua*. The destruction of healthy flesh is presumably associated with the secretion of a digestive fluid by the flies, for the mouth-parts do not possess any structures, for example, well-developed prestomal teeth, that could be used to rasp and tear the flesh. These flies can be very serious among sheep following the Mules operation (p. 137), castration, and docking. Healing may be seriously delayed and pathogenic micro-organisms conveyed into the wounds.

The bush-fly is incriminated as a vector of trachoma in man, and of conjunctivitis (blight) in cattle and sheep. It is also an intermediate host of the equine stomach worms, *Habronema muscae* and *Draschia megastoma*, which are extremely widespread and prevalent parasites in western areas. Other Australian species of *Musca* capable of acting as intermediate hosts of these worms include *M. fergusoni*, *M. hilli*, and *M. terrae-reginae*.

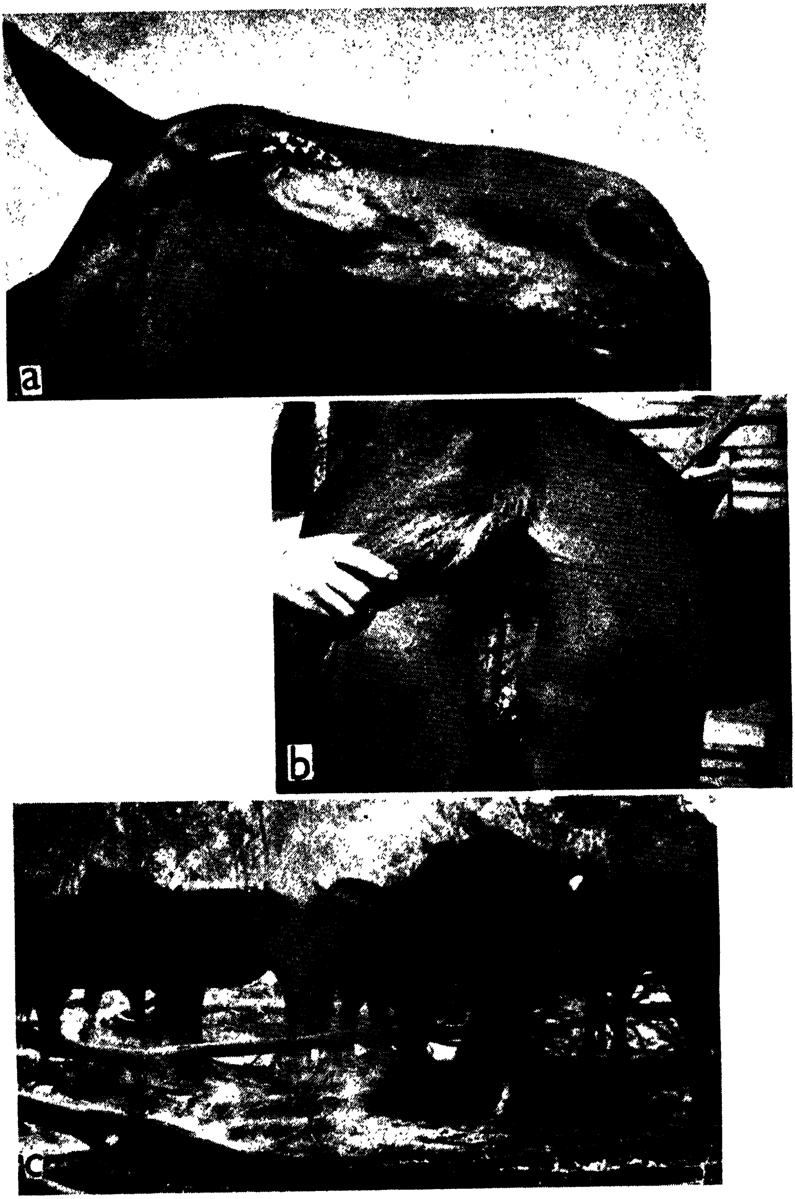

Fig. 76. The effect of heavy bush-fly infestation (*Musca vetustissima*) on horses. (*a*) Lesions round the eye; (*b*) lesions on the vulva; (*c*) horses standing in smoke to obtain relief.

(*After Moule.*)

Control. Owing to the conditions present in most western areas it is difficult to recommend any satisfactory measures of control. The main breeding places are unknown, and so at present control is confined to the adults. Of the various measures that suggest themselves, the use of DDT appears most promising. The treatment of animals, especially horses, with a 1 per cent DDT suspension as a spray or wash is well worth consideration. The intervals between treatments can be determined only by experience. Otherwise, all that can be recommended is the frequent mustering of horses and the segregation of badly affected animals close to the homestead to receive treatment. The wounds should be dressed and smeared with 2 per cent DDT in a vegetable oil. A leather fringe attached to a head-stall will protect the eyes.

The Stable Fly (*Stomoxys calcitrans* (Linn.))

In this species, the proboscis is porrect and readily visible, the palpi being short, about half as long as the proboscis. The thorax is grey with four longitudinal dark stripes, the outer pair being interrupted at the suture. The anterior dorsal borders of abdominal segments 2 and 3, and sometimes 4, are dark, the markings being prolonged medianly in the form of an interrupted dorsal stripe. Segments 2 and 3, and sometimes 4, are also each provided with a pair of lateral spots (Fig. 77). These abdominal markings, however, show a great deal of variation, and may at times become more or less confluent.

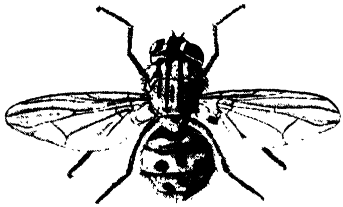

Fig. 77. The stable fly, *Stomoxys calcitrans.*
(*After Helmsing.*)

Habits and Life History. The stable fly is a cosmopolitan species, widely distributed throughout Australia. It is most prevalent in the coastal regions, but may occur in numbers also in inland districts. It appears to be most abundant during the summer and autumn when, between periods of activity, it may be seen in numbers resting on walls, rails, and posts. When resting, the fly assumes a characteristic attitude, the body forming an angle with the surface, with the proboscis projecting beneath the head and in line with the body.

Both sexes suck blood and will attack all classes of domestic animals and man. As a rule they favour the lower parts of the body, the limbs and belly, and in man, the ankles, though in the case of dogs the ears may receive considerable attention. They feed more readily in the early morning and late afternoon and tend to be somewhat sluggish during the heat of the day. In the warm weather the flies feed several times daily, but as the weather becomes cooler the intervals between feedings lengthen. When the insect is feeding, it often punctures the skin several times before it draws blood. The length of life may be as long as 3 to 4 months during cool weather, but in summer is not considered to be much longer than 3 to 4 weeks.

Before the female can oviposit, one or more blood meals are necessary. The eggs may be deposited singly or in clumps, but are not cemented together as are blowfly eggs. They are laid in such media as the mixture of manure and straw from stables, moist and rotting straw and other vegetation, and even in decaying piles of marine grass and sometimes in old caked manure. A single female may deposit up to 600 eggs. These are elongate, creamy-white in colour, and, under suitable conditions, hatch in 1 to 3 days. In summer the larvae may be fully grown in 11 to 30 days. In the absence of adequate moisture the growth of the larva may be considerably retarded and the maggots may even fail to mature. The puparium is brown, elongate-oval, and slightly broader at one end. The adult flies emerge in 6 to 20 days, or longer if the weather is cool.

Importance. There are no records from Australia to indicate that stable flies ever reach the pest proportions reported, for example, from coastal regions of Florida in the United States. There the flies breed in masses of seaweed and become so numerous that seaside resorts have to be closed. The milk yield of cattle is reported to decrease by as much as 20 to 25 per cent. In Australia, however, the flies are at times sufficiently numerous to irritate animals to a marked degree, and to interfere seriously with milking and other farm practices, such as ploughing.

The stable fly is an intermediate host of the equine stomach worm, *Habronema microstoma*, which is common in Australia, and of the cattle roundworm, *Setaria cervi*. The fly has also been incriminated as a mechanical vector of fowl-pox and anthrax, and of the trypanosome diseases in horses and cattle (see march-flies, p. 106). Of these diseases, only fowl-pox and anthrax occur in Australia, and the relationship of *Stomoxys calcitrans* to these diseases in this country has not been determined.

Control. Reports indicate that the treatment of animals with DDT is not a very effective means of protecting them, nor of controlling the fly populations. However, if advantage is taken of the insect's habit of resting on stable and dairy walls and on posts and rails, and these are treated with DDT as recommended for house-fly control (p. 111), stable fly populations will be effectively reduced. The breeding places, however, should not be neglected. Piles of manure and straw and any rotting vegetation should be dried out and burnt. If this is not feasible, they should be sprayed with DDT at the rate of 1 gallon of 1 per cent DDT emulsion or suspension per 100 square feet or with BHC, 0·1 per cent gamma isomer.

The Buffalo Fly (*Siphona exigua* (De Meijere))

The buffalo fly is recorded from India, the East Indies, Malaya, northern China, and Australia. It is a small fly, measuring 3·5 to 4 millimetres. The face is silvery-grey, the proboscis dark and porrect, and the palpi yellowish, stout, uniformly broad, and as long as the proboscis. The thorax is silver-grey medianly, darker laterally, with two well-defined dark stripes. The abdomen is brownish with a median longitudinal stripe, less conspicuous towards the apex. The legs are usually yellowish. The wing veins R_{4+5} and M_1 curve gently towards one another near the wing margin (Fig. 78(*d*)).

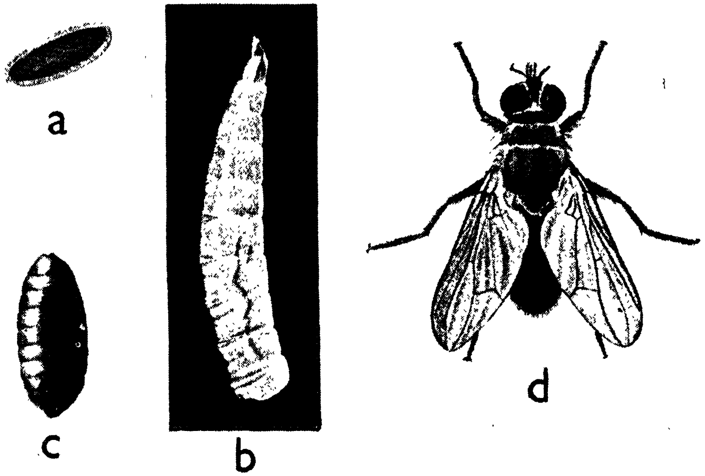

Fig. 78. The life cycle of the buffalo fly, *Siphona exigua*. (*a*) Egg; (*b*) larva; (*c*) puparium; (*d*) adult fly.

(*After Helmsing.*

Distribution in Australia. The buffalo fly arrived on the mainland in 1838 at Port Essington, in the Northern Territory, on water buffaloes and cattle brought from Timor to Melville Island some ten years previously. Its spread west and east from the Northern Territory was slow. It invaded the north of Western Australia in 1925 and quickly reached the western coast. Its first appearance in Queensland was in 1928, when it was found on cattle in the far north-west corner. Until 1939 its distribution in Queensland did not extend more than 130 miles east of the border. During these eleven years the fly's spread east and south was controlled both by unsuitable climatic conditions, mainly low rainfall, and by quarantine restrictions. However, the seasons of 1939 to 1941 were ones of exceptionally heavy and prolonged rainfall, as a result of which the fly moved eastwards very rapidly, to appear on the east coast of Queensland north of Cairns, from which it spread south. The areas occupied up to 1948 are shown in Fig. 79. The fly has never come very far inland, its distribution in this direction roughly corresponding to the 20-inch rainfall line. In Western Australia the southern limit at Wallal was reached in 1931. The fly is now well distributed throughout the Kimberley division, being most prevalent along the coast.

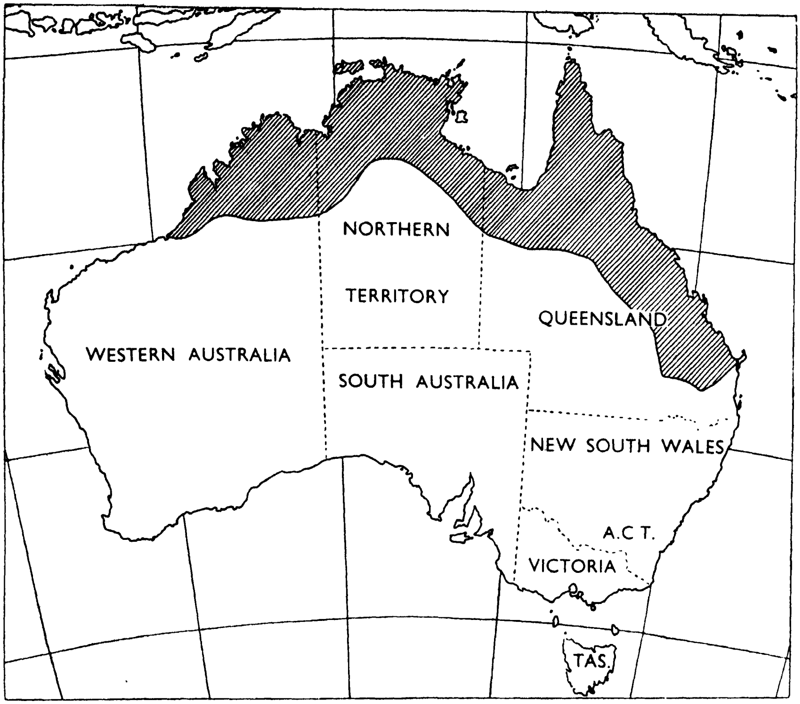

Fig. 79. The distribution of the buffalo fly, *Siphona exigua*, in Australia during May 1946 is shown by shading.

(*After Seddon.*)

Present indications are that the buffalo fly may not extend much beyond the areas shown in Fig. 79. Its spread southwards along the Queensland coast was rapid and in 1950 it appeared in the vicinity of Gympie, which marks the southern limit of its distribution. This was a year of excessive rainfall and the fly spread west as far as Blackall. Small numbers were also seen at Charleville. During the winters the fly rarely appears south of Rockhampton.

Habits. The buffalo fly is normally associated only with cattle and buffaloes. It will attack man, horses, mules, sheep, pigs, and dogs, but only when these hosts are with cattle, for the fly can live only where its bovine hosts occur. It is a blood-sucker, both sexes living in this manner, and it has a rather painful bite. When this fly is resting on an animal or feeding, the wings are held at an angle from the body, and under cool conditions, when the flies are sluggish, the wings are held flat along the back in scissor fashion. When feeding, the fly crawls down between the hairs of the coat and thrusts its head downwards on to the skin surface, so that its body appears to be at an angle to the skin, the wings being held horizontal to its body. It does not usually walk about on the host for any distance, but flies from one part of the body to another. The buffalo fly can be considered almost a permanent ectoparasite, in that it rarely leaves its host, remaining on it night and day, except for a brief flight following disturbance or to transfer to another animal, or to lay its eggs.

The flies are found in greatest profusion round the withers and shoulders and on the flanks, but may be scattered in fair numbers over the neck, ribs, and back (Figs 80, 81). Some flies may also be seen on other parts of the body, such as the legs and head, particularly round the eyes and on the horns. In rainy and windy weather they move to the more sheltered areas and may burrow down among the hair. When disturbed they rise in a short, quick, vertical flight and rapidly settle again. During flight they do not hover or dart about. Heavily infested animals are accompanied

Fig. 80. Heavy infestation of the buffalo fly, *Siphona exigua*, on a bull.
(*After Mulhearn.*

by swarms of flies continually rising in flight as the animal attempts to dislodge them, and then settling again.

Bulls are usually most heavily infested and may carry some thousands of flies as compared with a few hundreds on the cows. Aged cows and animals in poor condition will attract larger number of flies. Even among healthy animals of the same age and sex, individual infestation varies widely, and this is probably attributable to differences in odour.

Buffalo flies dislike dust, and infested animals being worked or travelling under dusty conditions quickly lose their flies. This probably accounts for the heavy infestations on the leading animals in a mob of driven cattle, and the almost complete absence of buffalo flies from the animals in the rear.

Very little is known concerning the length of life of flies on cattle. Periods recorded are from 10 to 20 days. The chief factors influencing longevity are winds, temperatures, and humidity. Strong winds, low temperatures, and low humidities are very unfavourable, and when these conditions prevail, the fly population is rapidly reduced.

When removed from the host, the buffalo fly does not survive for more than 1 or 2 days, even under the most favourable conditions. Newly emerged flies may die within an hour or so, unless they find a host.

The spread of this insect throughout Australia has occurred mainly through the movements of infested cattle. Although capable of flying at least two miles, it is doubtful whether the insect can fly longer distances, firstly, because of the very close association between the fly and its host, and secondly, because of its very brief period of survival when removed from the host. However, flight cannot be altogether disregarded as a means of spread, for there is some evidence that infestations in certain islands off the mainland may have had their origin in flies that apparently did not travel there on cattle.

Owing to its appearance and habits the buffalo fly cannot be confused with any other species of fly associated with cattle in Australia. The fly most like it, *Hydrotaea australis* (Macq.), a small dark insect about the same size as the buffalo fly, differs in its habits. It does not bite, and runs round restlessly on the hide, particularly on the legs and belly. The buffalo fly never crawls or runs over the body; when it wishes to change its position, it always flies. Furthermore, *H. australis* never rests with the wings in the position described for *Siphona exigua.*

Life History. The eggs of the buffalo fly are deposited only in the freshly dropped dung of cattle and buffaloes. As soon as the dung is dropped the females fly down and lay their eggs in sheltered crevices. If these are deposited in places that dry out too quickly or are exposed to sunlight, they fail to hatch. The egg is somewhat sausage-shaped, creamy to brownish in colour and about 1 millimetre in length (Fig. 78(*a*)). Under favourable conditions hatching takes place in 18 to 24 hours.

The larva is a typical fly maggot and, when fully grown, measures up to 10 millimetres (Fig. 78(*b*)). On hatching, the larva immediately burrows into the dung and keeps on burrowing as the surface layers dry out. The amount of moisture in the dung is a very important factor in the development of the larva; the optimum moisture content is about 68 per cent. When the amount of moisture is increased from heavy continuous rains, or decreased during spells of dry weather, development is seriously affected and the larvae may die. Under normal summer conditions the larva completes its growth in 3 to 5 days.

Pupation occurs in the bottom layers of the dung or in the nearby soil. The puparium is typically hard, barrel-shaped, brown in colour, and about 4 millimetres in length (Fig. 78(*c*)). The adults emerge after a pupal period of 3 to 5 days. *H. australis* also breeds in bovine dung, and its puparium is very similar in size to that of the buffalo fly. However, it possesses a pair of dark curved spines, which are absent on the puparium of *S. exigua.*

Thus, under normal summer conditions, the life cycle of the buffalo fly occupies 7 to 11 days. Under cooler conditions, each stage in the life cycle is prolonged, so that during winter the life cycle may not be completed for 46 days or more.

The fly populations are at their maximum during the late summer and early autumn, immediately following the summer rains. Thereafter the onset of low temperatures and dry conditions causes a rapid decrease in numbers. In North Queensland, particularly in the coastal areas, although the numbers are considerably reduced during the winter the fly never disappears entirely, and with the onset of the spring storms the nucleus, which has survived the winter, increases rapidly. It is not known whether normal winter conditions in the areas beyond the southern limit of its present distribution in Queensland are sufficiently severe to cause complete eradication but it appears that this may be so.

Importance. There is no accurate information available about the losses caused by buffalo fly in Australia, but the constant irritation of thousands of flies must seriously affect the weight-gains and milk production of cattle. Reports of such harmful results from graziers and dairy farmers are somewhat conflicting, but it appears that animals suffer most severely when exposed to attack for the first time. Over a period of time the animals seem to develop a certain immunity to infestation.

To relieve the irritation, the animals rub the affected areas vigorously against tree-trunks and posts. They scratch round the eyes with the hindleg and as a result large raw areas are formed. These wounds are very attractive to the buffalo fly and to the bush-fly (*M. vetustissima*), whose continual presence on such tender spots is a further source of worry and irritation. Cattle from buffalo fly areas can readily be recognized by these buffalo fly "marks" (Fig. 81).

The importance of the fly depends, of course, on its numbers. Observations indicate that populations of up to one thousand flies are usually fairly well tolerated, whereas two to three thousand flies constitute a serious infestation.

Control. The buffalo fly is a vector of surra (*Trypanosoma evansi*) in Asia. In Western Australia and Queensland the spread of this fly has been delayed by restrictions on the movement of cattle from infested to non-infested areas. In Western Australia a belt of dry country to the south of the infested area is unfavourable to the fly, but to make certain that no spread occurs in this direction a buffer zone has been established south of Wallal, and all cattle north of this zone are sprayed before moving south. Cattle shipped to Fremantle by sea are also sprayed.

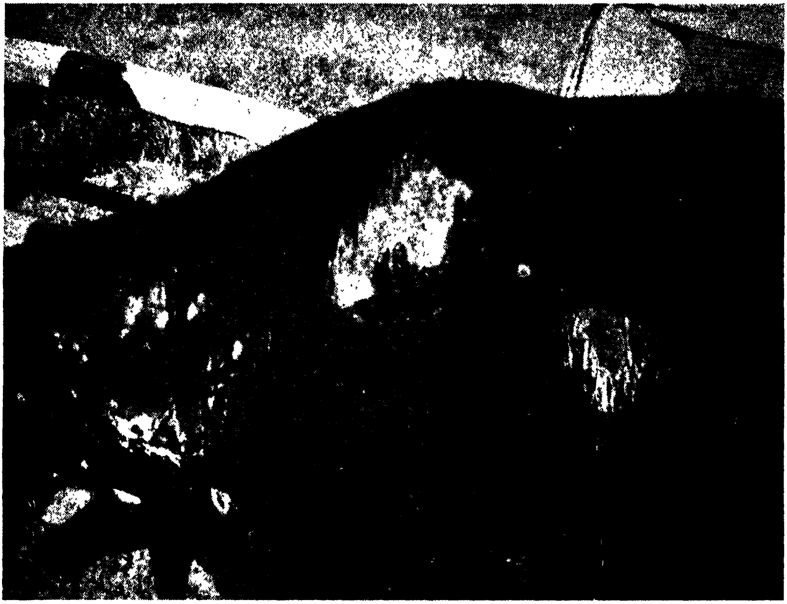

Fig. 81. Buffalo fly sores or "marks" on a cow.

(*After Mulhearn.*)

In Queensland, where DDT sprays are in use, stock moving from infested areas by train or on the hoof are sprayed immediately before departure. In the Northern Territory the flies disappear as soon as the animals move southwards into the drier areas.

Sprays. Within the fly zones infestation can be readily controlled by the use of DDT and traps. This insecticide can be applied in an oily solution (kerosene), as an emulsion, or as a suspension.

The use of a 4 per cent solution of DDT in kerosene is suitable mainly for dairy stock (1 lb. of DDT to 2½ gallons of kerosene). It is applied as a fine mist, by means of a household-type spray gun, to those areas of the body on which the flies occur in greatest numbers. To avoid any irritation to the skin, which might follow from too liberal applications of kerosene, only sufficient spray should be used to wet the hair. A few puffs to each area is all that is required, and when used at this rate 2 pints will give protection to moderate-sized herds for about a month. Treatment is carried out while the cows are in the milking bail.

A 4 per cent DDT emulsion or suspension applied to the shoulders and withers at the rate of 1 gallon for 80 head of cattle gives better protection than the kerosene solution. When the fly is very prevalent the DDT will protect for two to three weeks. For small numbers of animals, a hand continuous atomizer is satisfactory, but with a large herd a knapsack or bucket pump spray with an 0·03-inch nozzle will be more suitable.

With milking cattle the initial treatment should include all animals; thereafter, sprays need be applied only to those animals harbouring the greater number of flies.

Dips. Where DDT dips are installed for the control of cattle tick (*Boophilus microplus*), no trouble with buffalo fly is ever experienced. Indeed, the 0·5 per cent DDT concentration employed as Rucide, a proprietary formulation of a colloidal type, protects for a sufficiently long period—just over 14 days—to exceed the life cycle of the fly and bring about complete eradication. Reinfestation occurs when flies come in from surrounding untreated areas.

Where arsenical dips are still in use against cattle tick, the fly may be controlled by spraying cattle in the draining pen with a 2 per cent DDT emulsion or suspension by means of a knapsack or bucket pump spray.

BHC at a concentration of 0·025 to 0·05 per cent gamma isomer will also kill buffalo flies alighting on cattle, but the period of protection given by this insecticide at these concentrations is not long enough to give effective control.

Traps. These originated in the United States, where they proved very efficient against the horn-fly, *Siphona irritans*, which is similar in habits and economic importance to the buffalo fly. The trap recommended by the Department of Agriculture in Washington is built of wood, 11 feet long, 6 feet 8 inches high, with a roof and ceiling and 2 feet 10 inches wide. This is just wide enough to permit the animals to pass through one at a time. Each side is lined with three trapping boxes of fly gauze on wooden frames. The flies are dislodged from the animals by canvas strips suspended from the ceiling, which brush against the animals' bodies. When the beast has passed through, the strips fall back into place and prevent the flies from following it through the trap. The flies in the trap are attracted to the light coming through the gauze traps at the sides. Each trap is lined on the inside by gauze folded in a zigzag manner. The flies gather in the peaks of the folds and enter the box traps through small holes. Here they are held captive and die.

This type of trap has proved very effective against the buffalo fly under Australian conditions, but certain modifications suggested by Australian workers give a more simple design without sacrificing any efficiency. The roof of the Australian trap is peaked, and both the roof and sides covered with glass. The gauze fly-trapping boxes have been eliminated, the death of all the flies captured in the trap being ensured by treating the glass with DDT (Fig. 82).

With a little patience there should be no difficulty in getting cattle to go through the trap. They should be driven in several times before the canvas strips are hung; then the strips can be added gradually, and the animals will become accustomed to going through them.

The more often a herd passes through the trap, the greater is the degree of control over flies. On dairies the trap should be erected in a position where it will be used by the cows both before and after milking. Since most dairy farmers milk twice daily, the cows would use the trap four times in 24 hours.

It should be possible to train beef cattle to pass through a trap of this type, though much more patience and supervision would be necessary.

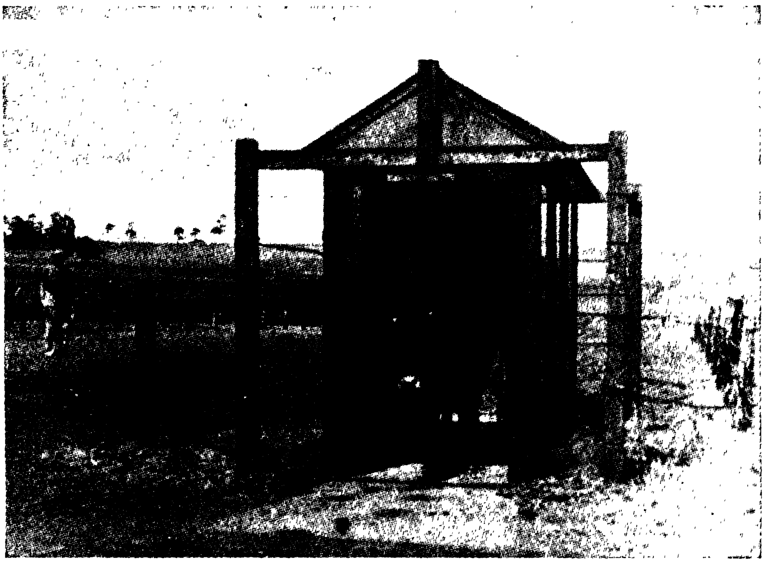

Fig. 82. An efficient buffalo fly trap with DDT-treated glass sides and roof. (*After Norris.*)

Tsetse Flies (*Glossina* Spp.)

The tsetse flies include a number of extremely interesting and important species that are confined to Africa.* These include *G. tachinoides* Westw., *G. palpalis* R. D., *G. pallidipes* Austen, *G. morsitans* Westw. *G. brevipalpis* Newst., and *G. synnertoni* Austen, and are all narrow-bodied, yellow to brown or black, blood-sucking flies from 6 to 13·5 millimetres long, with the wings, when at rest, folded in scissor fashion along the back (Fig. 83). The venation is characteristic for the genus.

The name "tsetse fly" is best known in association with the African disease of man known as sleeping sickness (*Trypanosoma gambiense* and *T. rhodesiense*), which is carried by *G. palpalis* (*T. gambiense*), *G. tachinoides* (*T. gambiense*), and *G. morsitans* (*T. rhodesiense*). The flies are also serious pests to domestic animals in Africa, for they are vectors of a dangerous disease known as nagana (*T. brucei*, *T. vivax*, and *T. congolense*), which is transmitted by many species, of which *G. morsitans*, *G. pallidipes*, and *G. palpalis* are the most efficient vectors.

**Glossina tachinoides* is said to extend into south-west Arabia.

Habits and Life History. Within the area of their distribution the species are confined to "fly belts". Each shows a certain selectiveness in its choice of habitat, which may not be suitable to any of the others. This choice is apparently governed by certain requirements of the species, and is concerned with resting, feeding, and breeding. The resting haunt appears to be associated with certain types of vegetation and with moisture, the breeding places with certain "furniture", such as leaning or fallen logs, overhanging rocks, leaf-mould, and type of soil, etc., and the feeding places with areas suitable as a habitat for the wild animals on which the flies feed.

The egg hatches in the uterus of the fly and the larva is not deposited until fully grown. When this occurs the larva immediately burrows into the vegetation or soil and in about 30 to 90 minutes has pupated (Fig. 83). Adults emerge in about 17 days, though this stage may be delayed as long as 12 weeks.

Control. Tsetse fly control has received considerable attention in Africa, and various measures have been recommended that depend upon the species it is desired to control. These include the following:

1. Using traps designed to take advantage either of the flies' preference for resting or breeding places, or of the principle that they hunt by sight, or of their response to odours; the Harris trap, which is built to simulate an animal, is one of the most successful.

2. Rendering the vegetation unsuitable; for example, by clearing

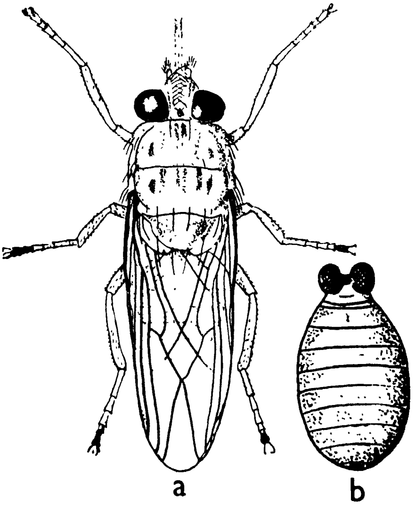

Fig. 83. A tsetse fly. (*a*) Adult, (*b*) pupa.
(*After Smart.*)

it or by planting dense thickets through which the flies cannot penetrate.

3. Controlling the wild animals on which the flies feed, and which are the reservoirs of the diseases they transmit. Control methods include wholesale slaughter, keeping game on the move, and making the country unsuitable for the animals.

4. Application of DDT and BHC aerosols, by spraying them from aircraft, a method that has only recently been tested, and that has proved most promising.

Blowflies and Screw-worms

The majority of blowflies breed in carrion and act in this way as Nature's scavengers. Some species attack living animals, their larvae occurring on or in the flesh, but in most cases the flies can complete their development in both carrion and living flesh. A few species are confined to the living animal and include the screw-worm flies, such as the New World *Callitroga hominivorax* (Coquerel) (*Cochliomyia hominivorax*), which is present in tropical and subtropical America, and the Old World *Chrysomyia bezziana* Villen, of India, the Philippine Islands, and tropical and southern Africa. These are notorious pests and cause considerable economic loss, for they will attack any animal and sometimes birds, being attracted to blood, pus, dried exudate, the natural openings of injured or unclean animals, and the navel of newly born animals. Cattle, sheep, and goats are chiefly concerned.

One African species, the tumbu fly, *Cordylobia anthropophaga* (Greinsberg), which will attack any animal, lays its eggs in places frequented by the host, such as bedding, clothing, and sand contaminated with excreta. The larvae, on hatching, burrow into the skin of the first animal they contact. Another species of the same genus, *C. intonus* Aldrich, which occurs in the East Indies and the Philippine Islands, lays its eggs on the hairs on the lower parts of the legs of cattle, buffaloes, and goats. On hatching, the maggots burrow into the skin. This infestation of living animals by the larvae of flies is known as myiasis. When it occurs in the region of the skin it is called cutaneous myiasis.

Throughout the world, myiasis is one of the most important diseases of sheep and cattle.

Cutaneous Myiasis in Sheep

Cutaneous myiasis, or to use the Australian term, "strike", in sheep is a serious problem, and a cause of considerable economic loss in Australia, Great Britain, South Africa, New Zealand, and the United States. Undoubtedly the problem is greatest in Australia, where it was estimated some years ago to be responsible for a loss of at least £4,000,000 annually.

Species of Blowflies Concerned in Strike. In Great Britain the green bottle, *Lucilia sericata* (Meig.), is the most important species, other species concerned being *L. caesar* (Linn.), *L. illustris* (Meig.), *Phormia terrae-novae* (R.D.), *Calliphora crythrocephala* (Macq.) and *C. vomitoria*

(Macq.). In South Africa *L. cuprina* (Wied.),* *L. sericata*, and *Chrysomyia chloropyga* (Wied.) are mainly involved, while *C. albiceps* (Wied.) is of minor importance. The American species of "wool maggots" include *Phormia regina* (Meig.), *L. cuprina*, and *L. sericata*, and occasionally some species of *Calliphora*, whilst in New Zealand *C. laemica* White and *L. sericata* are the species usually bred from struck sheep.

In Australia seventeen different species of flies have been recorded from cases of strike, ten of which are blowflies. *L. cuprina* is the most important of these, occurring throughout Australia wherever strike is recorded, and being responsible for about 80 per cent of strikes. It is an introduced species, probably from Africa, and is a medium-sized fly, bright metallic green, sometimes bronzy, in colour, with silvery-white face and cheeks (Frontispiece (3) and Fig. 84 (*d*)). The thorax has a number of strong bristles, and the legs are black, the thighs of the first pair frequently being bright green (Frontispiece (4)). *L. cuprina* may be found all the year round, but has marked peaks of abundance in the spring and autumn. Its maggots are smooth and creamy. *L. sericata* has also been introduced into Australia, but is not important among sheep. It can be distinguished from *L. cuprina* by the dark thighs of the forelegs (Frontispiece (5)) and by certain characters of the head, thorax and abdomen.

There are several species of *Calliphora*, all native, and these are particularly prevalent during the winter and spring, being most abundant in southern Australia. *C. augur* (Fabr.) (Frontispiece (2)) is widely distributed throughout eastern Australia. It has a grey thorax, and a yellowish-brown abdomen with a large area of dark blue in the centre and over the apex. This species is next in importance to *L. cuprina*.

In Western Australia *C. augur* is replaced by *C. nociva* Hardy, a very similar fly. The large brown blowflies *C. stygia* (Fabr.) (Frontispiece (1)) *C. fallax* Hardy, and *C. australis* Boisd. are all alike in appearance, being most robust than *C. augur* and having a grey thorax and a dark-brown abdomen with patches of golden dust. The maggots of the calliphoras are all smooth and creamy.

Chrysomyia rufifacies (Macq.)(Frontispiece (6) and Fig. 84(*h*)) resembles *L. cuprina*, but it is a more robust fly and is darker green with a bluish tinge. The thorax is less bristly and the abdomen has narrow dark bands at the junctions of the segments. The maggots are brown with dorsal tubercles (Fig. 84 (*f*)), from which the popular name of "hairy maggot" is derived. *C. micropogon* (Bigot) (Frontispiece (8)) is a robust, dark, steely-blue fly, tinged greenish when alive, with a bright-orange face and cheeks. Its maggots are smooth and creamy.

Species of little importance include *Microcalliphora varipes* (Macq.) (Frontispiece (7)), a very small green species with black and yellow-brown legs and "hairy" maggots, and *Peronia rostrata*, a black blowfly.

Habits and Life History. It has been determined that these blowflies always react to carrion or to an attractive sheep in a definite succession.

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*There are two subspecies of *L. cuprina*, one from the Oriental and American regions (*L. cuprina cuprina*) and one from the African and Australian regions (*L. cuprina dorsalis*).

The primary flies arrive shortly after the death of an animal and are the first to lay their eggs on the carcass. Similarly these primary flies initiate strike on a susceptible sheep. After their maggots have been at work in the carcass or on the sheep for some time, the carcass or the animal becomes attractive to the secondary flies. Finally, when the carcass has reached the last stages of decay or the strikes on the living sheep are very old, tertiary flies arrive and lay their eggs. The primary flies, which include *L. cuprina* and the species of *Calliphora*, are thus the most important, for in their absence strike would not occur, or would at least be confined to infected wounds. The secondary flies are *Chrysomyia rufifacies*, *C. micropogon*, and *M. varipes*. *P. rostrata* is a tertiary fly.

There are no distinct strains of flies that attack sheep in Australia; the flies that do so will readily lay their eggs also in carrion. The life cycles of the various species associated with strike are very similar, differing only in detail. That of *L. cuprina* is selected as an example.

The newly emerged female fly immediately seeks a meal of animal protein, without which the ovaries will not develop. Provided that mating has occurred, the first eggs are laid five to seven days later. These are deposited in carrion or in the wool of the live sheep, usually in batches of 100 to 250. They are banana-shaped, and creamy-white in colour (Fig. 84 (*a*), (*e*)). As many as 3000 eggs may be laid by a female during her lifetime, though many of the eggs deposited during the later periods of life may be infertile. The incubation period depends on a number of factors, such as temperature and humidity, and under normal summer conditions the larvae emerge in 12 to 24 hours. Some species of *Calliphora* deposit eggs that hatch immediately after being laid.

The newly hatched larvae, if on the sheep, move down to the skin surface and feed there. The maggots produce digestive juices that liquefy their food, though they are capable of tearing off minute, solid particles, which they devour whole. This mode of nutrition is assisted by bacteria that predigest insoluble matter and make it available to the larvae. On the sheep the larvae can grow on the exudate from the irritated skin and also on moist scales in the fleece. They may on occasions penetrate the skin, but this is dependent on the species and also on the duration and intensity of the infestation.

The maggot is fully grown three to six days after hatching, when it is a little more than half an inch in length (Fig. 84(*b*), (*f*)). It then drops from the sheep or wanders from the carrion, seeking a place to pupate. In summer this usually occurs in the soil in about two days, but in winter the prepupal stage may extend as long as four months. The puparium is typically brown and barrel-like (Fig. 84 (*c*)), but that of *Chrysomyia rufifacies* still retains the tubercles so characteristic of the larva (Fig. 84 (*g*)). In summer the adult fly emerges after about eight days, the complete life cycle, egg to adult, at this period of the year, occupying about seventeen days.

Adult flies may live as long as three months in captivity. *C. rufifacies* has been known to travel 10 miles in twelve days, and *L. cuprina* nearly 5 miles in 30 hours.

Types of Strike. The various types of strike are designated according

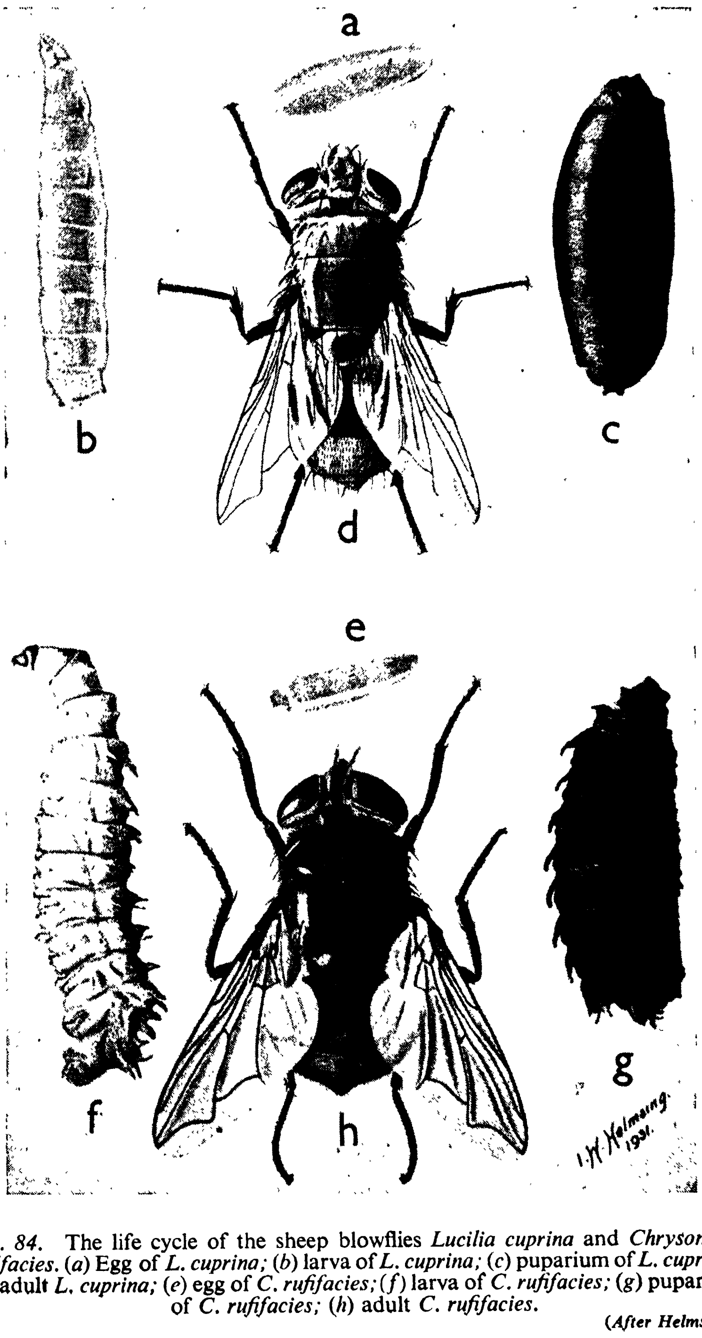

Fig. 84. The life cycle of the sheep blowflies *Lucilia cuprina* and *Chrysomyia rufifacies*. (*a*) Egg of *L. cuprina;* (*b*) larva of *L. cuprina;* (*c*) puparium of *L. cuprina;* (*d*) adult *L. cuprina;* (*e*) egg of *C. rufifacies;* (*f*) larva of *C. rufifacies;* (*g*) puparium of *C. rufifacies;* (*h*) adult *C. rufifacies.*

(*After Helmsing.*)

to the part of the body attacked. These are (*a*) crutch strike, (*b*) body strike, (*c*) head strike, (*d*) pizzle strike, and (*e*) tail and purse strike of lambs following tail-docking and castration.

Crutch Strike. This is the commonest form of strike, sheep being struck on the breech or on the tail. Although it is most common in ewes, it can also occur in wethers and rams.

Body Strike. This is the term used in referring to strike anywhere on the body except in the region of the crutch, tail, head, and pizzle. It is usually seen on the withers, the flank, the point of the shoulder, and the mid-ventral line of the neck. These areas are associated with the natural drainage lines for moisture running down from the back. Body strike occurs mainly during periods of abnormal spring and autumn rainfalls accompanied by mild temperature conditions. It may also be associated with heavy dews and long grass.

Head Strike. This is usually confined to rams, and affects the region at the base of the horns.

Pizzle Strike. This is seen in young rams and wethers in the region of the prepuce.

Lamb-marking Strikes. These are confined to the tail and purse of lambs following docking of the tail and castration.

Effects of Strike. Although crutch strike is the most common type of strike, body strike is the most severe. During the two days following the occurrence of strike, the animal shows little evidence of disturbance beyond twitching its tail and stamping. The area may later become very inflamed and the maggots may break through the skin, causing the wound to become hot, swollen, raw, and weeping. The animal's temperature rises, and has been known to reach 108° F. After the maggots leave, the animal gradually recovers and a hard scab covers the damaged area, which eventually lifts. The old fleece comes away and a new one grows. Sometimes the wound becomes septic, thus delaying healing.

In cases where the wound is continually being struck, it increases in size and becomes attractive to the secondary flies, whose maggots extend it widely by burrowing in pockets beneath the skin. The animal's condition becomes worse and it may die, probably from a combination of exhaustion and the absorption of toxic substances derived from the disintegrating tissues. Should the animal survive, the fleece not only lifts away from the affected area, but the constitutional disturbance may cause a severe break in the fleece.

Occasionally reference is made to "lightning strike", when the sheep dies within a few days after being struck. This is usually attributed by the grazier to a new and "vicious" fly. Little is known of this type of strike, but undoubtedly it does occur. The fly concerned is undoubtedly *L. cuprina*, and the rapid deaths are probably associated with some markedly pathogenic organism that has been conveyed into the wound.

The losses from strike are due, firstly, to the loss of wool, which lifts from the wound or is shorn away in treatment, and to decreased wool values due to tenderness or break; secondly, to loss of condition, and mortalities; and thirdly, to the expenditure involved in handling and treatment and in the application of preventive measures.

Conditions Under Which Strike Occurs. Before strike can take place, certain factors involving both the flies and the sheep must operate. Firstly, primary flies must be present and must not only be attracted to the sheep, but must oviposit. Secondly, conditions on the sheep must be favourable to the establishment of the maggots.

Factors Governing the Prevalence of Primary Flies. The severity of a fly-wave depends on the degree of abundance of primary flies, particularly of *L. cuprina.* Cold, dry winters and hot, dry summers are associated with either a very low degree of strike or none at all, for under these conditions *L. cuprina* occurs only in small numbers. Prolonged showery and warm humid weather, on the other hand, is ideal, and causes a rapid increase in the flies. Strike is most troublesome during the autumn and spring, when such weather most frequently occurs, and if the winter is warm and wet the flies are also troublesome then.

The populations of *L. cuprina* are built up mainly from maggots infesting sheep, carrion playing only a very minor role in this regard.

Factors that Render the Sheep Attractive. Sheep are attacked not by chance but because they become attractive to gravid female flies. Two factors are involved in this condition of susceptibility, a sheep or "S" factor that attracts the fly and a putrefactive or "P" factor that stimulates oviposition. The P factor may be supplied by bacteria, which thrive under moist conditions. The presence of moisture also irritates the skin, causing it to become inflamed and weeping—also a source of attraction.

In crutch strike, these conditions are most prevalent in sheep with very wrinkly breeches (Fig. 85(*b*)). The breech folds, and also those on the tail, retain moisture and so make these areas attractive to the fly. Plain-breeched sheep are the least susceptible (Fig. 85(*a*)). Some of this moisture is provided by body secretions, but mainly by urine and also by diarrhoea, when these excretions are delivered so that they contaminate the breech. Under continuous showery, warm, and humid conditions the incidence of breech strike increases rapidly and even plain-breeched sheep may be attacked. Sheep with bad conformation of the hindquarters, such as "turkey hocks" and narrow breeches, are very susceptible, for these conditions are not conducive to the free delivery of urine, and also delay subsequent drying.

In pizzle strike the area becomes susceptible because it is kept damp by urine. Sheep with balanitis are attractive to flies. Similarly with head strike in rams; although this type of strike occurs in wounds from fighting, it is frequently a sequel to moist conditions at the base of the horns similar to those occurring in breech wrinkles.

Body strike becomes most serious when there has been continuous wet, warm, humid weather. Under these conditions bacteria on the skin and in the fleece increase rapidly and cause fleece rot, when the wool is leached and matted with the formation of a crust on the skin surface. As the wool grows, the matted material is lifted from the skin, and if successive periods of dry and wet weather occur one or more bands of this material may be seen in the fleece, and these may be green, purple, pink, red, brown, or yellow, but usually greyish, yellowish, or light brown in colour (Fig. 86). Fleece rot is very attractive to the flies, which strike

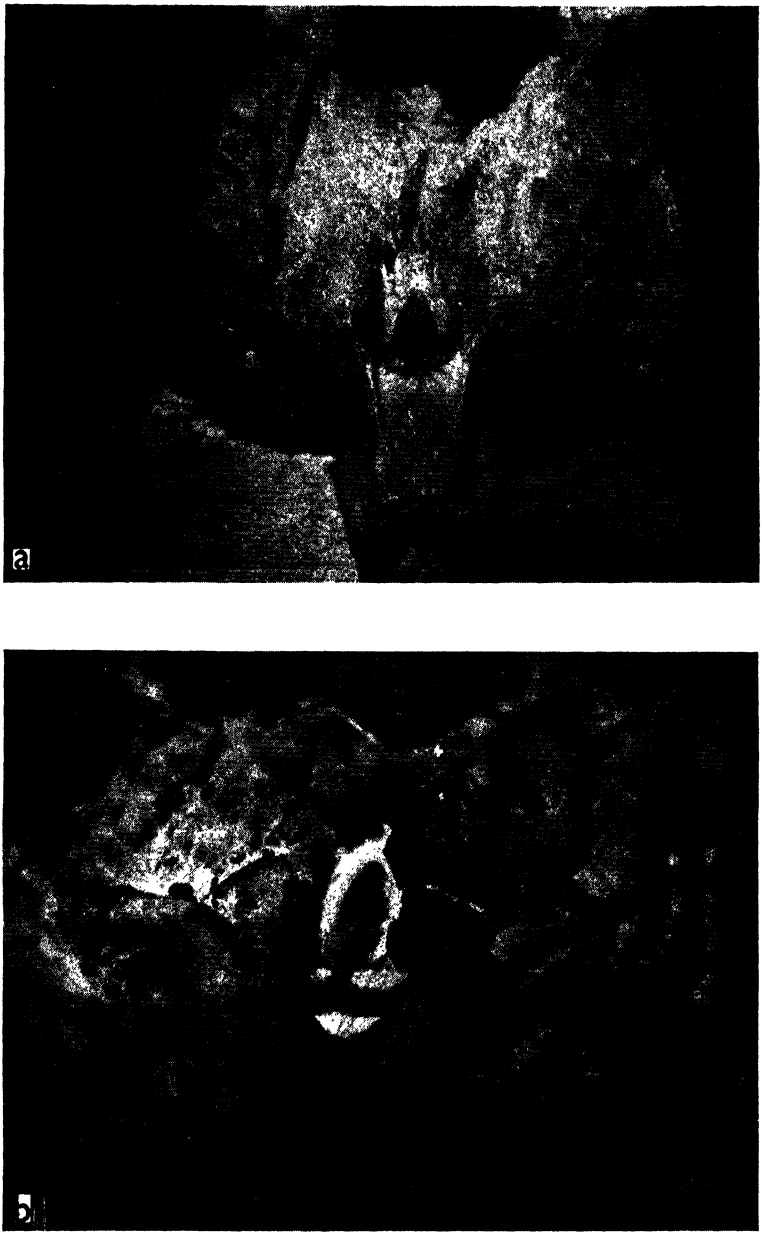

Fig. 85. The relationship of breech conformation to susceptibility to breech strike. (*a*) Plain-breeched sheep; (*b*) wrinkly-breeched sheep.

where the condition is active. Fleece rot that originates during prolonged wet weather does not necessarily require rain to become active again, for the moisture may be provided by long grass wet with heavy dews. Fleece rot and body strike are intimately associated, and the susceptibility of sheep to this condition is concerned with factors that permit the fleece to become and remain wet. This form of strike is most prevalent among young sheep, probably due to the openness of the wool and the mobility of the skin, factors that are conducive to the wool being easily wetted.

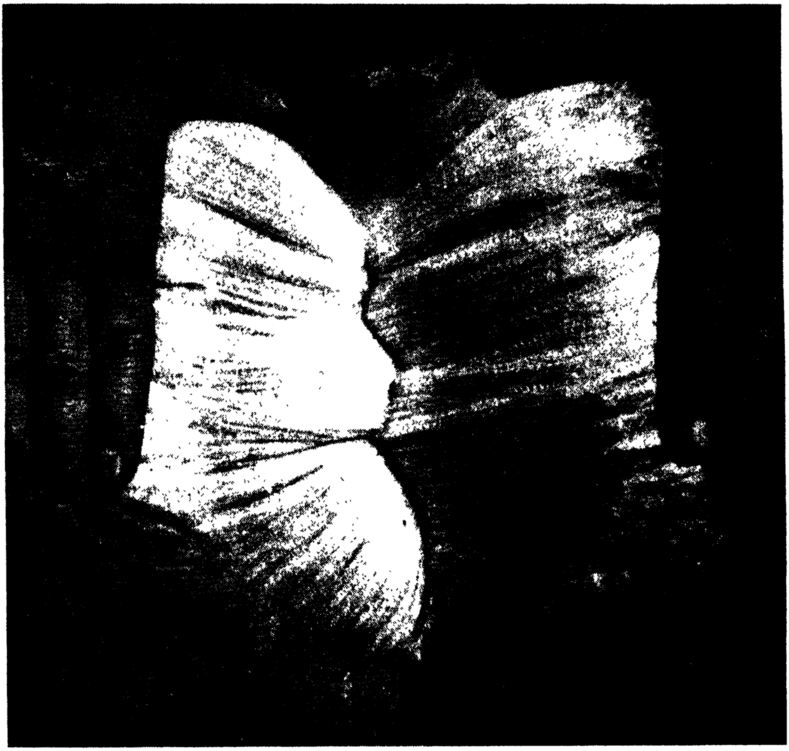

Fig. 86. Open fleece showing a band of fleece rot.

The withers are the most common site for body strike, and the predisposition here is associated with high shoulder-blades, broad withers with a depression between the shoulder-blades, and withers that are pinched behind, sheep with "devil's grip" being very susceptible. The type of wool is also considered by some workers to play an important role, sheep with open, slack fleeces or with fleeces that lack character and are harsh and yellow in colour, being most prone to strike.

The flies are also attracted to wounds and, if prevalent, may cause serious trouble after lamb-marking.

There is no doubt that the merino is far more susceptible to fly strike than other breeds of sheep. In Australia, strike among British breeds is of relatively little importance. On occasions trouble may be experienced with Corriedales.

CONTROL

Preventive methods aim at reducing the fly population, and protecting the sheep or rendering them unattractive.

Measures to Control the Fly Population

Since *L. cuprina* is the most important blowfly concerned in strike, the search for an effective control has been confined to this species. In this connection considerable attention has been given to carrion as a source of flies, and to trapping as a means of keeping the numbers in check.

Carrion Destruction. The ineffectiveness of carrion destruction as a control measure becomes apparent when the intense competition that occurs among fly maggots breeding there is known. *L. cuprina* arrives at the carcass soon after death and for a short time its maggots have an abundance of food. Further primary and then secondary flies arrive, mainly *Chrysomyia rufifacies*, and the carcass is soon a seething mass of maggots, all competing avidly for the available food. In this competition the primary maggots become seriously depleted in numbers. Some are driven out early through the shortage of food, others are eaten by the *C. rufifacies* larvae and by carrion beetles, but the majority are unable to withstand the high temperature generated in the carcass by all the activity, and are forced to leave, and die. As a result, only a comparatively few *L. cuprina* successfully complete their development to emerge as flies.

On the other hand, even a moderate-sized strike on the sheep will produce some hundreds and even thousands of this fly, for here there is little competition, and the temperatures are not unfavourable. It is becoming more and more evident that the main source of *L. cuprina* is the living sheep. It is very important therefore, that sheep should be closely watched for strike, which should be dressed immediately, and that the wool from the dressed strike with its large numbers of maggots should, if possible, be destroyed. There seems to be no doubt that the large fly populations that build up so rapidly under favourable conditions have their origin in strikes that are ignored by the grazier because they are so few in number.

The destruction of carcasses is, of course, desirable for the purposes of general hygiene. It might be possible to exert some small degree of control of primary flies by treating the animal carcass within a few days after death with borax, arsenic, or possibly BHC, in order to kill the primary maggots breeding there. However, this matter has yet to be explored, and nothing is known of the part played by small animal and bird carcasses in the dynamics of blowfly populations.

Trapping. In trapping, advantage is taken of the attractiveness of carrion to blowflies. It is used as bait, the flies attracted thereto being able to enter the trap, but once inside they cannot escape. Early work in trapping soon demonstrated that though large numbers of blowflies were caught, only a very small percentage was *L. cuprina*, and few of these were gravid females. This is because *L. cuprina* is attracted to the carrion bait for oviposition purposes only whilst the bait is comparatively fresh, thereafter visiting it for feeding only. Liver is used as bait, and when fresh liver is treated with sodium sulphide its attractiveness to *L. cuprina* is considerably enhanced. With this bait, and using traps at the rate of 1 to every 25 acres, a 50 per cent reduction in strike was obtained in one experiment. But under these conditions trapping becomes impracticable, since the large number of traps required on the average-sized sheep property in Australia would make this measure unmanageable and uneconomic. However, there is still much work to be done before trapping can be wholly condemned. The type of trap and bait is capable of improvement, and the effectiveness of the trap has not yet been tested during periods when there are only a few flies present; the control of these might considerably lessen the severity of a wave when conditions become favourable for a serious outbreak, or might even prevent such an outbreak.

Measures to Protect the Sheep or to Render it Unattractive

Included here are measures that reduce the immediate susceptibility of an animal, in which case only temporary relief is given, and measures that provide more permanent control by eliminating the natural predisposition of the animal to strike.

Shearing and Crutching. By the removal of the fleece the parts of the body that are especially susceptible to attack are given an opportunity to dry out rapidly, and urine contamination is reduced. These areas thus become unattractive to the fly and unsuitable for the development of strike. Shearing is probably the most effective method of reducing susceptibility to body strike, and if it is carried out just prior to or at the beginning of a body strike wave it will usually provide protection during the period when the flies are active. However, there may be many practical difficulties in carrying out this measure at the time when it will give the best results, as, for example, the availability of shearers, lambing dates, and the prevalence of grass seeds.

Crutching is a common practice adopted to prevent crutch strike, and if done efficiently it gives considerable protection. The area shorn includes the crutch, over the tail, and down the back of the hindlegs. One crutching at mid-season prevents the occurrence of excessively dirty crutch wool at shearing.

Wrinkly breeched sheep cannot be crutched as cleanly as plain-breeched animals.

In the case of pizzle strike, shearing of the wool from round this region will give good protection.

Jetting, Dipping and Spraying. This procedure is employed mainly to protect the crutch, though it may also be used to prevent body strike, head strike, and pizzle strike. Jetting consists of forcing a jet of water containing a maggot poison into the fleece so as to saturate the areas susceptible to strike. In Australia, work on jetting mixtures has been confined mainly to arsenic. Sodium arsenite (0·7 per cent As_2O_3) and calcium arsenite (1 per cent As_2O_3) have been extensively tested, calcium arsenite, a suspension, being considered superior. It will give protection under severe conditions for four to five weeks. Sodium arsenite is less expensive and is easier to prepare, but under similar fly-wave conditions it will protect for only about three weeks. These arsenical preparations do not prevent oviposition by flies, but poison the maggots as soon as they begin to feed.

A single test made in Australia with DDT (0·5 per cent) applied to the crutch as a jetting fluid gave no evidence that it was any more effective than calcium arsenite. In trials in South Africa a 5 per cent emulsion protected sheep from crutch strike for periods up to three months, whilst 0·5 per cent gamma isomer BHC gave even better protection.

Sodium arsenite and calcium arsenite are delivered under pressure through nozzles one-sixteenth or five-sixty-fourths of an inch in diameter. The pressure varies according to the density of the wool, but if too great it will injure the skin and cause arsenical poisoning. The pressure used should be the lowest at which the fleece can be quickly wetted to the skin, and 40 to 90 pounds' pressure is suggested for sheep with 4 to 20 weeks' growth of wool. The operation is carried out in specially designed races. When jetting with arsenic for crutch strike, small strikes may be jetted with safety and advantage, but it is decidedly dangerous to jet large strikes. The wool in the crutch is filled with fluid, as is also a wide strip down each leg and over and including the tail, the free hand being used to ensure thorough wetting of both the fleece and the skin.

Where crutching and jetting are relied upon to control crutch strike, it will be found best to jet the sheep in the spring at the onset of fly activity. Jetting is repeated as often as required till midsummer, when the sheep are crutched. Jetting is practised again in the autumn and repeated until the flies disappear at the onset of cool weather.

Dipping in arsenic (0·2 per cent) is not as effective against crutch strike as jetting, and gives only limited control under conditions of severe body strike.

DDT (1 per cent para para) and BHC (0·05 per cent gamma isomer) applied to the fleece of the sheep have given very satisfactory control and one treatment, if given at the right time, may usually be expected to protect sheep for the duration of the outbreak.

Application may be made in a plunge or shower dip or by spraying the fleece by hand, using a coarse spray delivered at pressures of 100 to 150 pounds. When hand spraying the fleece tips should be saturated to a depth of about one half inch and it is not necessary to extend treatment beyond the area commencing from behind the ears, along the back, to and over the tail and extending about half way down the sides. Particular attention should be given the natural drainage lines.

DDT is recommended when treatment is carried out in anticipation of a wave, whereas BHC, (0·1 per cent gamma isomer) because of its superior toxicity to the maggots, gives better results once strike has commenced, the struck areas and surrounding wool being thoroughly saturated.

These insecticides also give good protection against head strike.

Fogging sheep with DDT or BHC has, in recent years been given some prominence as a method of controlling body strike, the sheep being enclosed in a tent or shed and the insecticide blown in as an aerosol or fog. Observations indicate that some protection may be expected, but this is by no means as lasting as that given by dipping or spraying.

The Modified Mules Operation. In this surgical operation, sufficient loose skin is removed from each buttock to ensure that when the wound heals the area of bare skin round the vulva is stretched and enlarged and the wool on each side is drawn away from the midline and from the stream of urine (Fig. 88(*b*)). It ensures that the wool in this region is no longer wetted by urine, thus reducing its attractiveness to flies.*

The Mules operation is called after its originator, Mr J. W. H. Mules, of Adelaide, South Australia, who first drew attention to its possibilities. It has since been considerably modified by C.S.I.R.O. workers and greatly increased in its efficiency. It is the most progressive step in blowfly control discovered in Australia, and is a remarkably efficient preventive measure. Applied when the sheep is young, this operation greatly reduces susceptibility for the remainder of the animal's life. It is applied with the greatest advantage to wrinkly-breeched sheep, but will give added protection even to plain-breeched animals. Recent observations have also indicated that if a median strip of skin is removed from the dorsal length of the tail, the wool-free skin is subsequently drawn upwards from the underside and tip of the tail on healing, and in this way, by eliminating wetting with urine, the tail is also protected from strike.

The main objections raised against the modified Mules operation are that it is cruel and that it disguises wrinkly-breeched sheep. In reply to the first charge it may be said that in skilled hands the operation is carried out quickly and easily, healing is rapid, and sheep are protected from the pain of crutch strike for the remainder of their lives. The second objection comes from breeders who are afraid it might upset their breeding policy. Actually this is not so, for the experienced sheep stud master can readily detect a wrinkly-breeched sheep despite this operation.

The operation consists of removing a single strip of skin from each side of the buttock with sharp dagging shears (Fig. 87), which are kept clean and disinfected. The wounds are crescent-shaped, and commence about an inch above and to one side of the butt of the tail, passing along the edge of the bare area round the vulva, continuing one or two inches below it, and then turning upwards to finish on the inside of the leg just above the top of the hamstring. The wound should reach its greatest width of about 2 to 2½ inches just about the level of the vulva (Fig. 88(*a*)). The main point to be remembered is that as much loose skin as possible should be removed, but not the underlying muscle. In wrinkly sheep the operation usually includes the median fold, but actually the strip of skin is removed from the same site irrespective of the position, distribution, and size of the fold.

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*The bare area round the vulva may be also enlarged by removing the skin round the perineum by chemical means. This is known as the Manchester treatment, and gives a protection as effective as the modified Mules operation. The main disadvantage of the Manchester treatment is the delayed healing that occurs in many sheep.

No subsequent treatment is applied to the wounds, healing is rapid and is usually complete in about three weeks (Fig. 88(*b*)). During this period the sheep should not be disturbed.

The operation can be effectively carried out only on sheep that have been freshly shorn or crutched. Sheep of any age may be treated, but it is con-

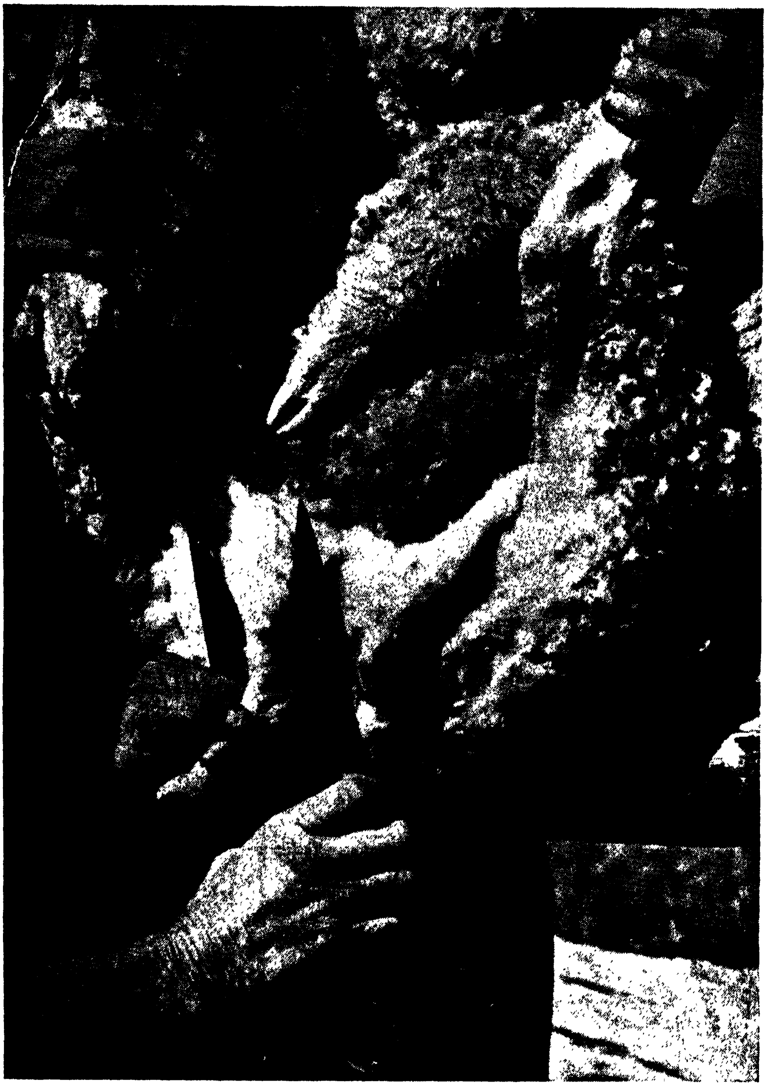

Fig. 87. The modified Mules operation in progress.

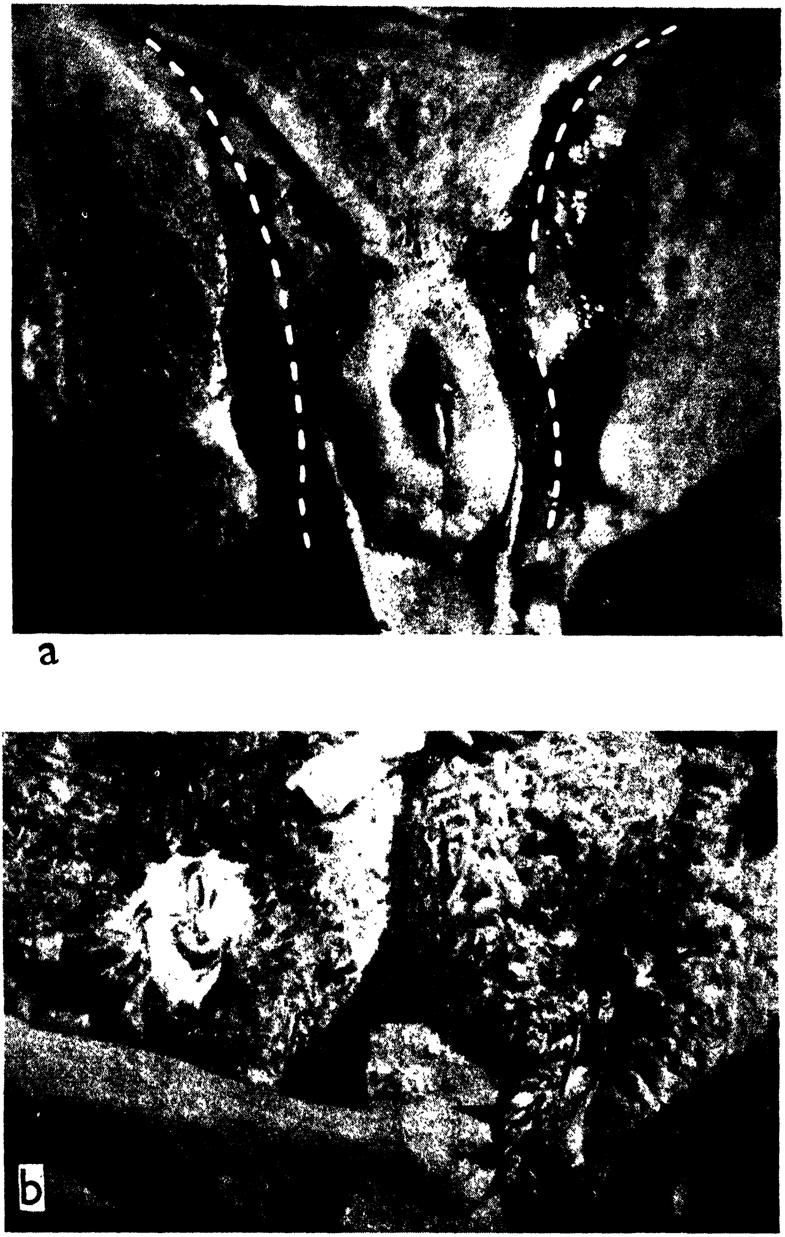

Fig. 88. (*a*) The completed Mules operation; (*b*) the operation after healing. Note the stretched bare area round the vulva in the mulesed sheep on the left. The sheep on the right has not been operated upon.

(Fig. (a) after Australian Wool Board; Fig. (b) after Moule.)

sidered that weaning time is most convenient. Some graziers prefer to "mules" the lambs when they are being marked, but the growth of wool on the older lambs does not favour treatment at this time. All sheep in a flock should be done and not only those that show any degree of wrinkling of the breech. Clean conditions should prevail, and the selection of clean yards, damping down of dust. and disinfection of shears will help to eliminate infection. The sheep are held on a rail as for marking, except that the hindlegs are held so as to slacken the skin of the breech. Special cradles are used when large numbers of sheep are to be treated. The choice of time for the operation must be given careful consideration, and should be confined to periods when blowflies and bush-flies are not active, otherwise serious losses may occur.

Tail Length. The length of the tail has a very important bearing on predisposition to crutch strike, as has also the manner in which docking is done. Observations of the effect of tail length on strike incidence have shown that the short tail favoured by most graziers increases susceptibility, whereas the best protection is given by tails that are cut to between a quarter and half an inch below the tip of the vulva. As the lamb grows, this relationship of tail-tip to vulva-tip is maintained.

Tails cut to this length heal more quickly than tails cut short, and the younger the lamb is when docked, the quicker the healing will be. If the skin is pushed forward by the knife before cutting, the tail heals with a bare tip, a further safeguard against strike.

Thus the modified Mules operation and tailing at the proper length are the two most effective methods for preventing crutch and tail strike, and will, under normal fly strike conditions, reduce the incidence of crutch and tail strike to a negligible figure.

The main objections to docking lambs at the recommended length come, firstly, from graziers, who object to the appearance and claim that such tails become more daggy than short tails, an observation not confirmed by the scientific workers responsible for the recommendation; and, secondly, from shearers, who claim that it is more difficult to shear sheep with this type of tail and who demand special rates.

Selection and Breeding. One school of thought has strongly advocated selection and breeding towards a non-susceptible type of sheep as the most effective method of control. The factors associated with conformation, and the fleece that predispose to strike, are well known, and by the rigid culling of such sheep and the use of plain-bodied rams it is claimed that a relatively non-susceptible flock can eventually be established. Since nutrition plays a big part in the inherent potentiality for the development of skin-folds, it is obvious that selection on appearance alone, where this predisposing factor is concerned, can give no reliable indication of an animal's breeding ability. Furthermore, since the rams cannot be selected on appearance alone, but must be progeny-tested, such a method of reducing predisposition must be a decidedly long-range one. Selective breeding offers no immediate relief against the serious losses experienced, but there seems to be no reason why this ideal should not be given consideration whilst the flocks are in the meantime protected by the other measures outlined above.

Dressings. In applying dressings to struck areas it is essential that the wool be removed from the infested portion of the body so as to leave a rim of clean, dry wool round it. Sheep should be inspected regularly and frequently, for early treatment not only means quicker recovery and lighter losses, but is also an important measure in the control of *Lucilia cuprina.*

A considerable amount of work has been done in Australia on blowfly dressings, and the ideal dressing is considered to be one that has the following qualities: (*a*) it must drive out and preferably kill the maggots; (*b*) it must be harmless to the skin and wounds and must not stain or mat the wool; (*c*) it must dry the struck area and promote healing; (*d*) it must prevent restrike within a reasonable time, that is, until the original strike has healed; and (*e*) it must be easy to apply, and relatively cheap. A dressing has yet to be discovered that possesses all these qualities and that is capable of effective use under the varied conditions present in the sheep districts of Australia, but nevertheless some very good dressings are available. These include (*a*) glycerine diboric dressing, (*b*) camphor and boric acid emulsion or CBE, (*c*) boric acid, tar oil, and bentonite or BTB, and (*d*) boric acid, kerosene, and bentonite or BKB.

(*a*) *Glycerine diboric dressing.* This is made by adding 4 pounds of powdered boracic acid to 3 pounds of hot glycerine and heating to 300° F. until dissolved, when a further 10 pounds of cold glycerine is added and the mixture warmed and stirred till dissolved. This is one of the best dressings yet devised, but the present high price of glycerine restricts its use.

(*b*) *Camphor and boric acid emulsion or CBE.* The formula for this dressing is:

Potassium hydroxide	4·1	per cent by weight
Boric acid ..	10·05	,, ,, ,, ,,
Oil of camphor ..	13·2	,, ,, ,, ,,
Oleic acid ..	2·5	,, ,, ,, ,,
Water to make ..	100	,, ,, ,, ,,

(*c*) *Boric acid, tar oil, and bentonite or BTB.* The formula is as follows:

Boric acid ..	15	per cent by weight
Creosote and kerosene* (equal parts)	2	,, ,, ,, ,,
Bentonite (American)	3	,, ,, ,, ,,
Agral 2 ..	0·5	,, ,, ,, ,,
Water	79·5	,, ,, ,, ,,

(*d*) *Boric acid, kerosene, and bentonite or BKB.* The formula for this dressing is as follows:

Boric acid		15	per cent by weight
Kerosene ..	9·3 per cent	20	,, ,, ,, ,,
Lysol	5·4 per cent		
Orthodichlorobenzene	5·4 per cent		
Bentonite (American)		3·0	,, ,, ,, ,,
Agral 2		0·5	,, ,, ,, ,,
Water		61·5	,, ,, ,, ,,

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*The kerosene is ordinary lighting kerosene, with creosote 259 with a distillation range of 240° to 330° C.

Simpler but less effective dressings include (*a*) dry boracic acid; (*b*) 5 per cent copper sulphate (which stains the wool); and (*c*) zinc sulphate 1 oz., powdered starch 4 oz., carbon tetrachloride 8 oz., and water 7 pints.

No work has yet been done on the value of the chlorinated hydrocarbons as dressings. BHC, because of both its residual toxicity and larvicidal properties, appears particularly promising. Many proprietory dressings contain BHC and DDT and appear to be satisfactory. Dressings used in other countries include (*a*) diphenylamine, employed as the active constituent in screw-worm dressings in the United States, such as Smear 62 and (*b*) the South African formula, which is as follows:

96 per cent alcohol	40	per cent by volume
Mineral oil (SAE 60)	5	,, ,, ,, ,,
Mineral oil (C.I. fuel)	10	,, ,, ,, ,,
Cresol	2·5	,, ,, ,, ,,
Sulphuric acid	0·15	,, ,, ,, ,,
Benzol	21·175	,, ,, ,, ,,
Neutral creosote oil (B.P. 200°—240° C.	21·175	,, ,, ,, ,,

Dressings are applied after a thorough shaking. The area of strike is saturated, the mixtures being worked in by hand or with a brush.

Lamb-marking Dressings. These are applied to docking and castration wounds, mainly to protect them from strike. The dressings therefore contain repellents, of which citronella has been found most effective, but they frequently contain a maggot poison as well. It is important that they do not delay healing.

The best lamb-marking dressing is boric acid, citronella, and bentonite, or BCB. The formula for this dressing is as follows:

Boric acid	17	per cent by weight
Citronella (pure Ceylon)	8	,, ,, ,, ,,
Bentonite	3·4	,, ,, ,, ,,
Agral 2	0·6	,, ,, ,, ,,
Water	71	,, ,, ,, ,,

This is a more reliable dressing than citronella alone, though good results have been reported from a 10 per cent citronella-soap emulsion.

Myiasis in Cattle and Horses

In Australia, myiasis in cattle and horses is of relatively little importance. It does occur, however, and originates in wounds, particularly when infected. Only a very small percentage of man-made and accidental wounds are struck, but infestation is not uncommon, for example, in dehorning wounds of cattle, and in fistulous withers in horses. Nothing very much is known of the species concerned, but *Lucilia* sp. (it is uncertain whether only *L. cuprina* or *L. sericata* or both are concerned), *Chrysomyia micropogon*, and *C. rufifacies* have been bred from maggots taken from infested areas. *C. micropogon* is probably the most frequent species.

Flesh-flies (*Sarcophaga* Spp.)

Flesh-flies can be readily recognized by the grey thorax with its prominent dark stripes, and the grey and black chessboard or spotted ornamentation of the abdomen (Fig. 89).

A few species breed in decaying vegetation or excreta. *S. peregrina*, for example, is the parent of the maggots commonly found in earth closets in Australia. The majority of flesh-flies, however, have similar habits to blowflies. *S. froggatti* (Frontispiece (9)) Taylor has been bred from strike in Australian sheep, but is of little importance. Species of *Wohlfahrtia* are common causes of myiasis in other countries. *W. magnifica* (Schiner) is the common myiasis fly of Europe and Asiatic Russia. It also occurs in Africa. *W. vigil* (Walker) and *W. opaca* (Coq.) have been recorded from North America, where they are important among young animals.

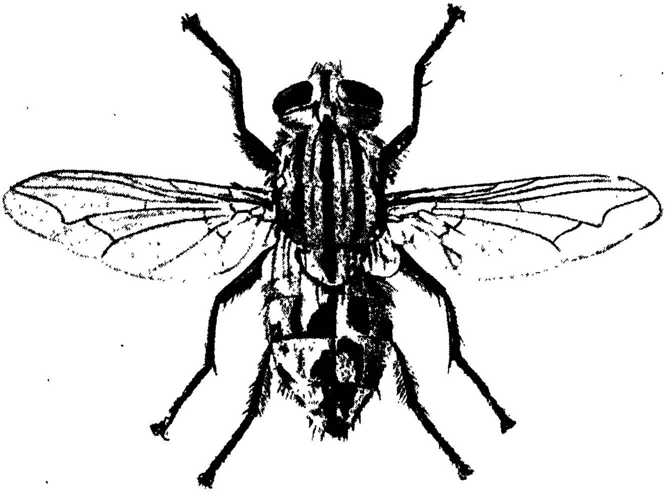

Fig. 89. A flesh fly, *Sarcophagus* sp.

(*After Helmsing.*)

Horse Bot-flies (*Gastrophilus* Spp.)

Horse bot-flies are yellowish to dark-coloured, hairy, bee-like flies. The mouth-parts are rudimentary and the flies are short-lived. The ovipositor of the female is long and is carried curved beneath the abdomen, giving the erroneous impression that these flies sting. The larvae are parasitic in the alimentary tract of equines.

Five species of *Gastrophilus* are recorded from various parts of the world as attacking horses and mules. *G. pecorum* (Fabr.) and *G. inermis* Brauer are European species, though the former also occurs in Africa, and the latter in the United States. *G. intestinalis* (De Geer), *G. nasalis* (Linn.), and *G. haemorrhoidalis* (Linn.) are world-wide, and include Australia in their distribution. *G. intestinalis* and *G. nasalis* occur in all States in Australia but *G.haemorrhoidalis* is recorded only from Victoria, New South Wales, and Western Australia.

The adult of *G. intestinalis* (Fig. 90(*c*)), the common bot-fly, is a hairy reddish-brown fly with dark abdominal bands. The wings are yellowish with a brown band and dark spots at the apex (Fig. 25(*b*)). *G. nasalis* (Fig. 90(*a*)) the throat bot-fly, has orange or red-yellow hairs on the thorax and greyish hairs with a broad band of dark hairs on the abdomen. The wings are clear, and cell M (anterior basal cell) is equal in length or almost so to cell 1st M_2 (discal cell) (Fig. 25(*a*)). *G. haemorrhoidalis*, (Fig. 90(*b*)) the nose bot-fly, has olive grey hairs on the head and thorax. The abdomen is grey-haired at the base, with a broad band of dark hairs and a bright-orange tip. The wings are clear and cell M is much smaller than cell 1st M_2.

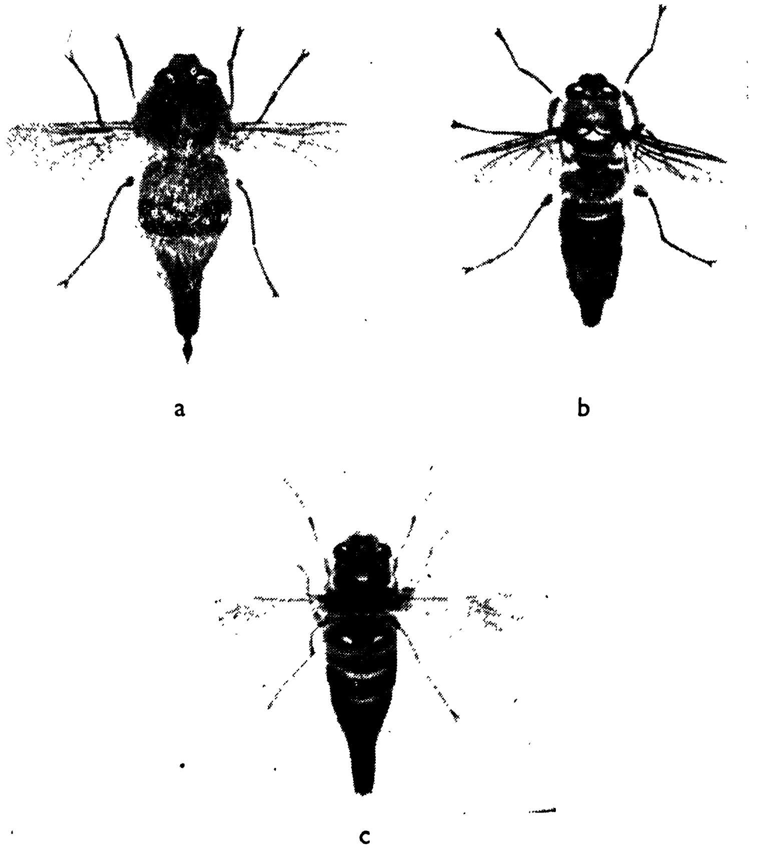

Fig. 90. Adult female horse bot-flies. (*a*) *Gastrophilus nasalis*; (*b*) *G. haemorrhoidalis*; (*c*) *G. intestinalis*.

(*After Hadwen and Cameron.*)

Habits and Life History. In Queensland the throat bot-fly is most prevalent during the spring and early summer, whilst the common bot-fly is an autumn and early winter species. The adults are sun-loving insects and rarely live longer than a week. The females hover near the horse, darting in very rapidly and depositing an egg, which is cemented to a hair.

The eggs of the various species differ in shape, colour, and manner of attachment to the hair. The egg of *G. intestinalis* is most frequently laid on the long hairs of the foreleg just below the knee, but is also seen elsewhere on the legs, on the mane, chest, and shoulders. It is dark in colour and is attached to the hair by a parallel flange extending from its posterior extremity for about half its length (Fig. 27 (*b*)). In the case of *G. nasalis* the eggs are laid on the hairs of the jaws, throat, and chest. They are yellowish-white and are attached by a parallel flange, extending almost the whole length of the egg (Fig. 27(*a*)). The eggs of *G. haemorrhoidalis* are deposited on the long hairs of the lips, and sometimes the nostrils. They are blackish in colour and have a long corkscrew-like stalk (Fig. 27(*c*)). Eggs of *G. intestinalis* are ready to hatch by the seventh day and the larvae are freed by contact with the animal's lips or tongue. They make their way into the mucous membrane of the lips, tongue, and cheeks, where they wander for several days. After leaving these tissues they attach to the oesophagus for a short time, eventually appearing on the left side of the stomach, where they remain to maturity.

The larvae of *G. haemorrhoidalis* hatch in about two to four days without any assistance from the host, and burrow into the skin of the lips and into the mucous membranes of the mouth, where they remain for about four weeks. They later appear in the pharynx, and finally in the stomach, where they are most numerous in the region of the pyloris.

The eggs of *G. nasalis* hatch in about six days and the larvae crawl unaided into the mouth Shortly afterwards they are found in pockets between the molar teeth, where they remain for three to four weeks. In the stomach they are seen in greatest numbers in and near the pyloris and in the duodenum.

During their passage from the mouth to the stomach bot-fly larvae frequently go astray and may be seen in other organs, and sometimes in the tissues under the skin.

The larvae are provided with a pair of strong mouth-hooks with which they anchor themselves to the mucosa, and in all species except *G. inermis*, there are rows of spines, the arrangement of which allows recognition of the various species (Fig. 26).

Maturity is reached in eight to twelve months, when the larvae detach themselves from the stomach wall and are passed out with the dung. On their way out the larvae of *G. haemorrhoidalis* re-attach to the walls of the rectum for a few days and again to the anus for two to three days before finally dropping to the ground. The fully grown larvae of *G. nasalis* when expelled are white in colour, whilst those of *G. intestinalis* and *G. haemorrhoidalis* are reddish.

Pupation occurs in the soil, the puparium being dark brown to black in colour with a spiny armature similar to that of the larva. The adult fly emerges in three to ten weeks, or longer, depending on the temperature.

Importance. The adult flies, in their attempts at oviposition, cause the horse a great deal of worry and annoyance, and its frantic efforts to escape from this results in runaways and interferes considerably with routine farm practices such as ploughing. Self-inflicted injuries are not uncommon.

Opinions vary as to the damage caused by the larvae. Some authorities consider that the bots do little harm beyond interfering with feeding during their sojourn in the mouth tissues, and with the passage of food through the stomach in the case of those species in the vicinity of the pyloris. Others consider that the bots may weaken the wall of the stomach and cause fatalities from acute peritonitis or abscess formation and gangrene in the spleen. The spiny armature and large mouth-hooks of the larvae indicate that inflammation and ulceration are very likely, with, at least, interference with the digestion (Fig. 91). It has also been noted that the excretions of the larvae are decidedly toxic, and in hypersensitive animals they may cause general debility.

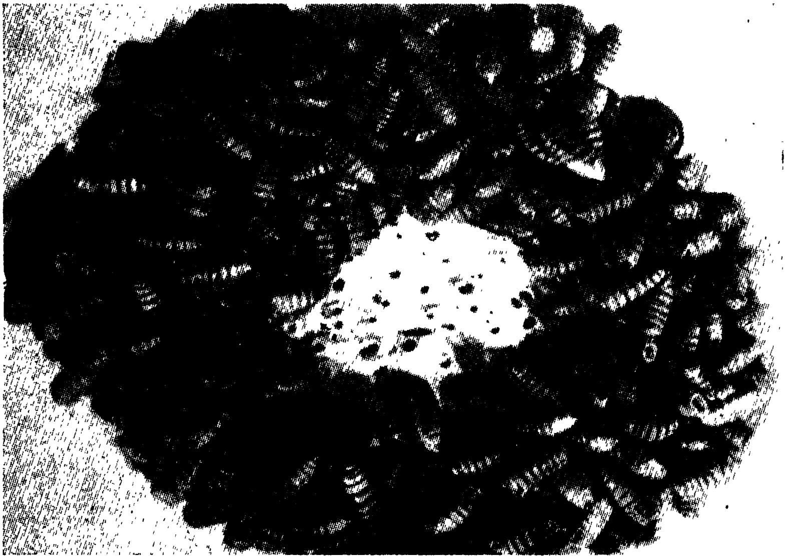

Fig. 91. Bot-fly larvae attached to the walls of a horse's stomach, with lesions in the centre.

(*After Dove.*)

Control. Control of bot-flies may be secured, firstly, by protecting the animals from the egg-laying activities of the females; secondly, by destroying the eggs; and, thirdly, by removing the bot larvae with efficient drugs. A piece of canvas under the jaw and over the throat protects this area from the throat bot-fly, whilst a fringe of leather suspended from a nose-strap over the lips, or a piece of leather 6 inches by 4 inches covering the lips, prevents oviposition by the nose bot-fly (Fig. 92). No device is available to protect the areas selected for oviposition by the common bot-fly. The flies dislike shade, however, and the provision of darkened shelters into which the animals can retire during periods of fly activity is claimed to be beneficial. Washes of DDT and BHC have apparently no effect on the egg-laying activities of the females. The eggs can be destroyed by vigorous washing with water heated to a temperature of 105° to 110° F. This stimulates hatching, and the larvae die.

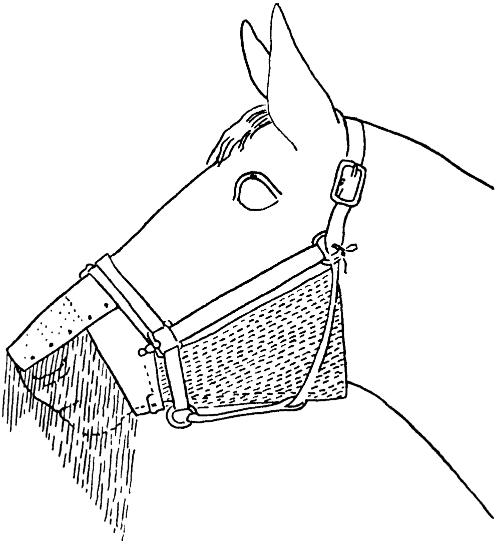

Fig. 92. Device for preventing oviposition by nose and throat bot-flies; the nose fringe protects from nose bot-fly attacks, whilst the leather or canvas flap attached to the head-stall and nose fringe wards off attacks by the throat bot-fly.

(*After Hadwen and Cameron.*)

The bots are most efficiently removed from the stomach with carbon bisulphide in capsules used at the rate of 6 drams for a 1000-pound horse. Treatment is preceded by an 18 hours' fast. A programme for bot control includes (*a*) washing with warm water (105° to 110° F.) at frequent intervals during the season of fly activity; (*b*) a final washing a few days after the last adult has been seen; and (*c*) after waiting a month to permit all larvae to reach the stomach, treatment with carbon bisulphide.

Warble Flies (*Hypoderma* Spp.)

Warble flies are very important pests of cattle, the mature larvae occurring under the skin of the host, in which they cut breathing holes. In this way they are responsible for serious damage to the hide. The adults are hairy flies, of which two species are known, namely *H. lineatum* de Villers and *H. bovis* de Geer (Fig. 93). They are confined to the northern hemisphere and occur in Europe, Asia and North America. The larvae have also been seen in the horse, sheep, and goat, and in man. The common warble fly of the goat in India is *H. crossi.*

Habits and Life History. The adults are sun-loving flies and are most prevalent during the spring and early summer. The eggs are laid on the hairs of the lower parts of the animals, *H. lineata* usually ovipositing when the animals are resting, alighting on the ground and approaching quietly. *H. bovis* is much rougher in its attack. Hatching occurs in four to seven days, the young larvae immediately boring into the skin and disappearing. The larvae of *H. lineata* reach the walls of the oesophagus via the chest and abdominal cavities, and from here they wander by way of the diaphragm and ribs to the region of the loins. Finally, about nine months after hatching, they reach the region of the back under the skin, in which they cut small breathing holes. Each larvae becomes enclosed in a cyst, feeding on the pus and other exudations in the cyst, and breathing through its posterior spiracles applied to the hole in the skin. Here they usually remain for two months, but sometimes for only five weeks.

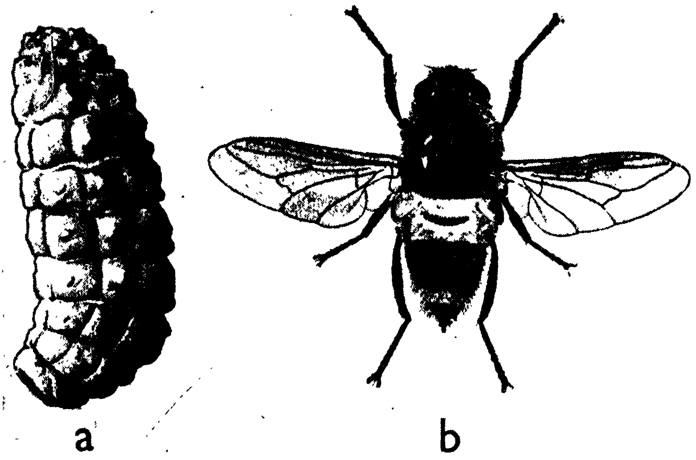

Fig. 93. (*a*) Fully grown larva of the cattle warble fly, *Hypoderma lineatum;* (*b*) adult female.

(*After Bishop.*

Little is known of the movements of *H. bovis* in the body, but the period occupied under the skin of the back is said to be about seventy-two days.

The fully developed larvae (Fig. 93) of both species eventually make their way out of the cyst and fall to ground, into which they burrow and pupate, forming a hard black puparium. The pupal period of *H. lineata* is about three weeks to two and a half months; that of *H. bovis* is shorter, averaging about four weeks.

Larvae occur chiefly in the back in an area extending about nine inches on each side of the vertebral column, from just behind the shoulders to the hip-bone. They are also seen on the rump, flanks, and in front of the shoulders.

Importance. The greatest loss occurs through damage to the hide, and this may be as high as 50 per cent. In addition, infestation is associated with a general inability to thrive, the difference in body-weights between infested and clean animals being as great as 16 per cent. There is also considerable loss of meat involved in trimming away suppurated areas of infestation, and during periods of fly activity animals are restless and terror-stricken, and may suffer serious accidents, loss of condition, and a decreased milk supply.

Control. DDT and BHC applied to cattle are not effective against the egg-laying activities of the female flies, nor do they control the adult fly populations. Rotenone is the most effective insecticide for the destruction of the grubs once they have taken up a position beneath the skin and cut their breathing holes. This is made up as a suspension in water—12 ounces of derris (5 per cent rotenone) in one gallon of water with 6 ounces of wettable sulphur (325 mesh)—and is applied with a stiff brush or as a fine spray at 250 to 300 pounds pressure. It may also be injected into the cysts by means of a syringe. The first treatment is carried out as soon as the cysts are big enough to justify it, followed by a further four to five treatments at monthly intervals.

The larvae may also be removed mechanically by pressure applied with the fingers, or with instruments such as forceps, or with a special suction apparatus.

The Sheep Nasal-bot (*Oestrus ovis* (Linn.))

The sheep nasal-bot is a stout, greyish fly about half an inch in length, ornamented with numerous small black spots, especially prominent on the thorax, which also has four indistinct dark stripes. The wings are clear and the body is covered with short hairs (Fig. 94). The mouth-parts are rudimentary and the adults are short-lived.

This fly is world-wide in distribution, and is well known throughout the sheep areas of Australia. The larvae infest the nasal cavities of sheep and occasionally also of goats. They are also recorded as causing ocular myiasis in man.

Habits and Life History. In warm climates the adults may be seen throughout the year, but where cold winters are experienced they are present only during the spring to autumn. They are most prevalent during the summer and most active during the warmer hours of the day. In the early mornings and late afternoons they may be seen sitting in the sun on such objects as water tanks, fly-screens, posts, tree-trunks, etc. They are said to be very restricted in their range of flight and not to migrate very far from where they have emerged. In the cooler months of the year the length of life varies from about one to four weeks, but in the heat of summer this may not be more than about two days.

The female fly deposits young larvae in the sheep's nostrils, each female being capable of depositing about 500 larvae during her lifetime.

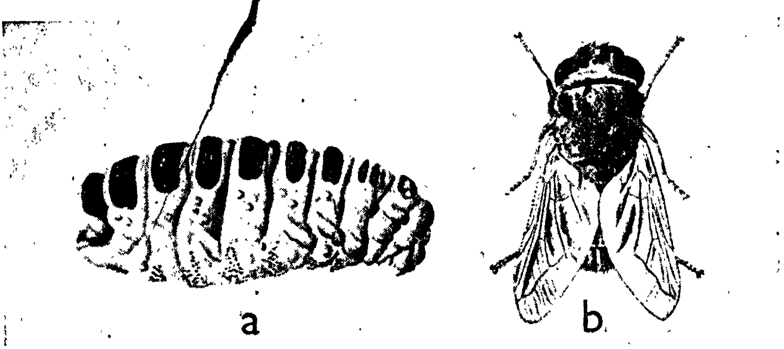

Fig. 94. (*a*) Fully grown larva of the sheep nasal bot-fly, *Oestrus ovis;* (*b*) adult female.

(*After Helmsing.*)

These immediately crawl onto the mucous membranes of the nasal passages, where they remain for periods of two weeks to nine months, attached to the mucous membranes by a pair of stout mouth-hooks. From here they eventually migrate to the frontal sinuses via the ethmoid turbinates, where the first moult occurs. Development is completed in the frontal sinuses (Fig. 95). Larvae sometimes wander into the horn-cores, but contrary to popular belief it is impossible for them to enter the brain cavity.

In warm climates larvae of all ages may be present throughout the year, but where the winters are cold the fly overwinters as first-stage larvae in the nasal passages. Full growth is reached in a minimum of 25 to 35 days,

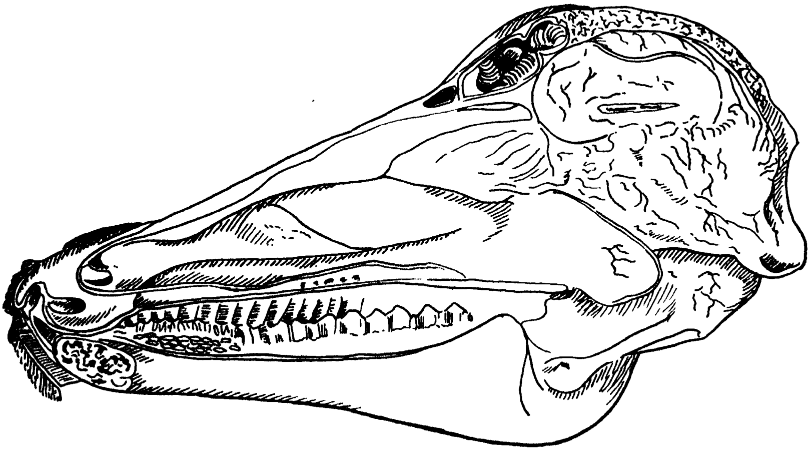

Fig. 95. Sectional diagram of sheep's head showing infestation with larvae of the sheep nasal bot-fly, *Oestrus ovis.*

(*After Curtice.*)

but this may be delayed for as long as 11 months. On reaching maturity the larvae crawl down into the nasal passages and are usually expelled by the sheep's sneezing. In warm climates larvae may continue to be expelled throughout the year, but in cold climates most larvae leave the sheep during the spring and summer. Some grubs enter cavities in the head, which are too small for them to leave when they are mature, and they die there. The younger larvae are whitish, sometimes yellowish in colour, whilst the mature larvae measure a little over an inch in length and are marked by a series of black bands on the dorsal surface (Fig. 94).

On reaching the soil the larvae burrow in and pupate. The puparium is black and seed-like. The pupal period is about four weeks in summer, but increases as the weather becomes cooler. Where pupation occurs in the autumn the flies do not emerge until the following spring.

Importance. The behaviour of sheep during periods of fly activity is very characteristic. The animals stand with their noses pressed into each other's fleece or held close to the ground, occasionally stamping the feet and shaking the head. Now and then they run about frantically.

Small numbers of larvae in the head passages apparently do little harm, but heavy infestations may be serious. The mucous membranes lining the cavities are irritated by the mouth-hooks and body spines and become inflamed and swollen. Secondary infection occurs with a copious purulo-mucous discharge known as "snotty nose", which together with the swollen membranes may interfere with breathing. The discomfort may result in impaired appetite, and loss of condition follows. In extreme cases the animal may die. It is also reported that the larvae may wander into the lung passages and cause pneumonia. Sneezing is a common symptom of infestation.

Control. Treatment is difficult owing to the location of the larvae. The methods of killing the larvae *in situ* include the following:

1. Injection of 3 per cent saponified cresol at 35 to 40 pounds pressure at the rate of 1 fluid ounce to each nostril. The head is held on the dorsal surface with the muzzle slightly elevated. This treatment is designed for cold climates and is directed against the first-stage larvae in the nasal passages. It is applied in the late autumn and early winter.

2. Injection into each nostril of 2 millilitres of equal parts of carbon bisulphide and liquid paraffin or 2 millilitres of equal parts of tetrachlorethylene and liquid paraffin, or 5 millilitres of 25 per cent tetrachlorethylene emulsion. The tetrachlorethylene emulsion as recommended in South Africa may be made by mixing 37·5 millilitres of tetrachlorethylene with 37·5 millilitres of liquid paraffin and adding this in small quantities to 25 millilitres of a 30 per cent soft soap solution, shaking to emulsify. Finally, 50 millilitres of water are added. The injection is made with a syringe fitted with a 2-inch piece of rubber tubing. During the operation the sheep is held flat on its back with the head at an angle of 45 degrees to the ground. The animal is held in this position for ten to fifteen seconds after the fluid has been injected. The success of this method of treatment depends on the quantity of mucoid discharge. If the discharge is excessive the treatment may not be effective.

3. Direct injection into the frontal sinuses through the bone by means

of a small guarded trocar and cannula, as recommended in South Africa. In horned sheep the site of the injection is just in front of the mid-horn base on either side. In hornless sheep the site will be found on either side of the middle of a transverse line drawn through the centre of the eyes, the distance being measured from above. The South African authorities recommend 5 millilitres of the 25 per cent tetrachlorethylene emulsion mentioned above for each injection.

There is no effective way of preventing the fly from depositing its larvae in the sheep's nostrils. Smearing the nose with pine-tar has frequently been recommended, but this has been shown to be of little value.

The Sheep Ked (*Melophagus ovinus* (Linn.))

The sheep ked is a wingless dark-brown insect 3 to 6 millimetres in length. The head is sunken into the thorax and is immobile. The body is furnished with short spines and the legs are stout, with strong claws (Fig. 96). This insect is sometimes erroneously referred to as the sheep tick. It is a common parasite of the sheep and has also been recorded from the goat and calf, though its presence on these hosts is probably accidental.

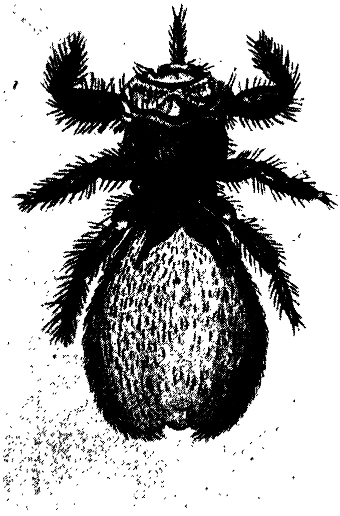

Fig. 96. The sheep ked, *Melophagus ovinus*.
(*After Helmsing.*)

The sheep ked is world-wide in its distribution and is known in all States in Australia. It is widely scattered throughout Victoria; in South Australia it is present in all sheep areas except in the south-east; in Western Australia it is confined to the higher rainfall areas of the lower south-east; in New South Wales it is seen mainly on the Tablelands and in Queensland it is seen only on the Darling Downs and on the Central Highlands.

Habits and Life History. Keds are permanent ectoparasites and live on blood and fluids, which they obtain by puncturing the skin of the host with their mouth-parts. The adults are found among the wool and on the skin of various parts of the body, but are most numerous in the region of the neck, shoulder, belly, and crutch.

The egg hatches in the body of the female and here the larva is retained until fully grown. It is then deposited as a pupa enclosed in a soft white membrane and is attached to the wool fibre some distance from the skin, the distance increasing as the wool grows. In long-woolled sheep, for example, these pupae occur from half an inch to one inch from the tip. In about twelve hours the pupae have hardened and turned brown. Most pupae are found in the wool on the ventral aspect of the neck towards the brisket, and on the lower parts of the side, whilst others may be seen on the belly and crutch. The pupal period varies from eighteen to thirty days, with an average of twenty-two days.

The females may mate within twenty-four hours of emergence, but fertilization of the ova does not appear to take place until four or five days later. The first pupa is deposited fourteen or fifteen days after emergence. The female may live as long as 130 days on the sheep, during which time she will produce ten to fifteen pupae, deposited, for a while at least, at the rate of one pupa every nine days. Newly hatched keds live for only four or five days when removed from the sheep, though at low temperatures this period may be increased. Pupae in detached pieces of wool will develop only if the temperatures are in the vicinity of 30° C.

Keds are most prevalent during the cooler months of the year, and decline in numbers as soon as the warm weather advances. Thus the populations are at a low ebb in summer.

Importance. These parasites cause considerable irritation and annoyance, as a result of which the animals may lose condition. Their efforts to relieve the irritation by biting, scratching, and rubbing seriously damage the fleece, which is further reduced in value by staining from the parasites' excreta. The ked transmits *Trypanosoma melophagium*, a harmless blood parasite of the sheep.

There is a wide variation in the susceptibility of individual sheep to infestation, young sheep and sheep in poor condition harbouring most parasites.

Control. As in the case of lice, contact between sheep is undoubtedly the most important manner by which keds spread throughout a flock. However, it is possible for clean sheep to pick up keds from detached pieces of wool lying in yards and shearing sheds. This danger is emphasized if, for example, clean sheep are brought in for shearing immediately following infested sheep.

Infested flocks are treated by dipping in some suitable insecticide. The discussion on p. 81 regarding dipping sheep for lice applies equally to dipping to control keds.

Arsenical dips (0·2 per cent As_2O_3) are fairly effective against adult keds, but some of the insects nearly always survive treatment. These dips do not affect the pupae and, not having sufficient residual effect, at least two dippings are required for effective control.

Under Australian conditions dips containing derris at concentrations of 0·0025 per cent rotenone have proved highly efficient against adult keds, but do not kill the pupae, nor does the derris remain in the fleece sufficiently long to kill all the keds that emerge from these unharmed pupae. A further treatment is necessary twenty-four to thirty-five days later. On the other hand, derris (5 per cent rotenone) at the rate of 8 ounces per 100 gallons of water is regarded as a highly effective single treatment in the United States, where it is preferred to DDT because of its cheapness.

Phenols are frequently incorporated with arsenic or derris as emulsions, containing about 0·4 per cent phenols. These emulsions are effective only against the adults, two treatments at an interval of twenty-four to thirty-five days being necessary for effective control.

Both DDT and BHC dips are highly effective against adult keds and persist in the fleece long enough to kill keds hatching from the pupae, which are unharmed. These insecticides can be used either as emulsions or as suspensions, and are employed at concentrations of 0·1 to 0·2 per cent para para isomer DDT and 0·01 to 0·03 per cent gamma isomer BHC, respectively. Reference should be made to p. 81, where these two insecticides are discussed in greater detail with reference to their use against sheep lice. Chlordane, 0·2 per cent, and toxaphene, 0·2 per cent, are also very efficient.

Where it is not advisable to dip sheep—for example, during very cold weather—keds can be controlled by using a 10 per cent derris dust containing 5 per cent rotenone and 2 per cent motor oil No. 10 in pyrophyllite, applied with a power duster. DDT and BHC dusts at concentrations of 10 per cent and 1 per cent respectively would also probably be effective.

Trials have been carried out with DDT and BHC applied as a fog to animals enclosed in a tent or shed. The results have been encouraging, but further work is required before it can be said that this method of treatment is satisfactory or otherwise.

Shearing will remove practically all the pupae and a high percentage of the adults, provided it is done carefully and with particular attention to the region under the neck.

The Horse Louse-fly (*Hippobosca equina* (Linn.))

The louse-fly of the horse is a small species, 9 millimetres in length, with brownish wings and a flat body with strong legs. The head is yellowish and the body brownish with yellow markings on the thorax (Fig. 97). The claws are bidentate. It is found chiefly on horses, but will also attack cattle, camels, and dogs. It occurs in Europe, Africa, and Australia. Though not a common insect in Australia it is recorded from horses in Queensland and from horses and cattle in Western Australia.

Habits and Life History. The adults are most prevalent during warm, sunny weather and, although provided with wings, do not fly any distance, being spread chiefly by means of their host. The fully grown larvae are deposited singly in the soil, where it is dry and where abundant humus is present, and they pupate almost immediately. The pupal period depends mainly on temperature and moisture.

Importance. The blood-sucking activities of these flies cause considerable irritation, which is all the more severe because the flies, when feeding, tend to cluster together. They prefer the perineal and pubic regions and the inner surfaces of the hindlegs.

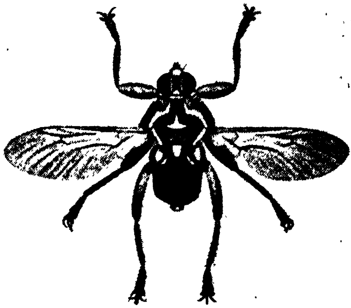

Fig. 97. The horse louse-fly, *Hippobosca equina.*
(*After Stekhoven.*)

Control. DDT and BHC sprays as recommended for lice should give good control (p. 72).

The Pigeon Fly (*Pseudolynchia canariensis* (Macq.))

The pigeon fly is a winged, flat, brownish insect (Fig. 98), a little smaller than the house-fly. It attacks pigeons and related birds in Europe, Africa, India, North and South America, and Australia. It has been seen in Australia only within recent years and is present in Queensland, South Australia, and Western Australia.

Habits and Life History. The flies live on blood and are capable of very rapid movements among the feathers of the host. They may be seen on any part of the body, though on squabs they are most frequent at the bases of the wing and tail feathers. The parasite will leave the birds only after considerable disturbance, when it has a quick, erratic flight and is attracted to moving objects.

The pupae are deposited by the females among the feathers and drop off into the nest and into cracks and crevices in the loft. They are at first pale yellow in colour, but within three hours have become black and shiny. The adults emerge in about twenty-five to thirty-one days, or longer in cold weather. Each female lays four to five pupae and may live up to forty-five days.

Importance. Infestation causes severe irritation, which is most serious among the squabs, and heavy infestations have been reported as causing mortalities among these young birds. This parasite also transmits the organism of pigeon malaria, *Haemoproteus columbae.*

Control. Thorough cleansing of the loft and the destruction of all debris is the first essential for control. The nests should be carefully lifted out, any adhering pupae brushed off, and the nest box then tilted so that the pupae can be collected and burnt. The birds are dusted with pyrethrum, derris, or DDT dusts (10 per cent). DDT sprays (5 per cent) are liberally applied to the nests and lofts to kill any pupae in the cracks and crevices.

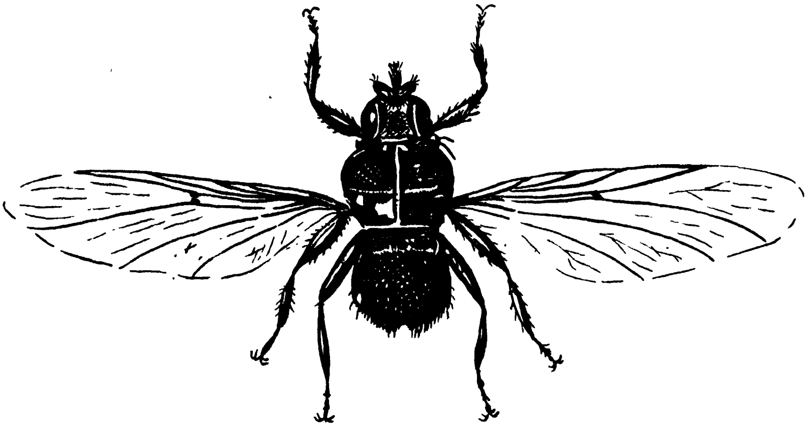

Fig. 98. The pigeon fly, *Pseudolynchia canariensis.*
(*After Patton and Cragg.*)

SECTION III

CLASS ARACHNIDA

In the class Arachnida the body consists of an anterior cephalothorax or prosoma formed from the fusion of head and thorax, and a posterior abdomen or opisthosoma, typically composed of a number of segments. In some cases there is no demarcation between the cephalothorax and abdomen, which may be unsegmented. There are one pair of chelicerae, which take the form of pincers, curved claws, or piercing stylets, one pair of pedipalpi, tactile and leg-like in appearance, and four pairs of legs. Respiration is by tracheae and, in some species, by book-lungs.

CLASSIFICATION. Four sub-classes are recognized, the Limularia, Merostomata, Pectinifera, and Epectinifera. The Pectinifera, which contains the scorpions, and the Epectinifera, with the spiders, mites, and ticks, are the only sub-classes of veterinary interest.

Order SCORPIONIDA (Scorpions)

Cephalothorax and abdomen distinct; chelicerae small and chelate; pedipalpi large and also chelate; abdomen consisting of seven broad anterior segments and five slender posterior segments, with a terminal spine in the form of a poison sting; respiration by book-lungs (Fig. 1(*g*)).

The posterior abdomen or "tail" contains a pair of poison glands whose ducts unite and open just in front of the terminal spine. The sting is poisonous and frequently causes intense local pain, and in some species, such as the North African *Buthus* and the Central American *Centruroides*, may be fatal to man. There is no information available regarding the toxicity of scorpions to livestock. Apparently where harmful species occur, only an odd animal is affected. There are no very harmful scorpions in Australia.

Order ARANEAE (True Spiders)

Body composed of a cephalothorax and an unsegmented abdomen, usually soft and globular; pedipalpi simple; chelicerae subchelate and containing the ducts of poison glands (Fig. 1 (*f*)).

All species secrete venom to kill their prey, but only a comparatively few species are seriously toxic to man and animals. The American black widow spider, *Latrodectus mactans* (Fabr.), and the allied Australian "redback" and New Zealand "katipo", *L. hasseltii* (Thorell) (Fig. 99), are, however, highly dangerous, and their bite may have serious effects, which are sometimes fatal.

These are medium-sized blackish spiders with a red marking on the globular abdomen. The bite is followed by extreme pain in the legs and abdomen, rigidity of the abdomen, high blood pressures, and high temperatures. The Australian species is very common, particularly in country areas, where it spins its loosely woven, tunnel-like web among all kinds of litter, in heaps of timber, under fence rails, and in dark corners under chairs and beneath the seats of privies. These spiders may be killed by spraying with 10 per cent DDT or with creosote. Other Australian spiders recorded as being poisonous to man are *Euctimena tibialis*, a trapdoor species, *Atrax robustus* Cambridge and *A. formidabilis* Rainbow, which are funnel-web spiders.

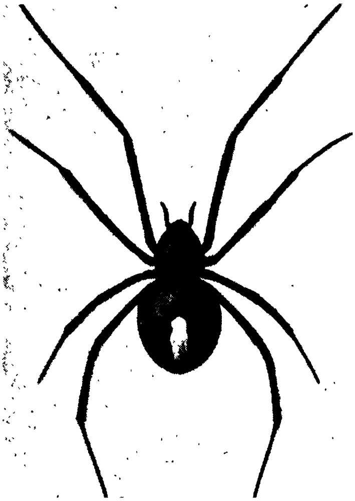

Fig. 99. The redback spider, *Latrodectus hasseltii*.
(*After Taylor.*)

Order ACARINA (Mites and Ticks)

Abdomen unsegmented and broadly united with the cephalothorax, so that in most species there is no demarcation between the two; mouthparts variable, suctorial, but frequently capable of biting and piercing; integument soft or leathery, frequently with chitinous plates; larvae with three pairs of legs, adults and nymphs with four pairs (Fig. 1 (*h*),(*i*)).

CLASSIFICATION.* The order Acarina is divided into several sub-orders.

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*Some acarologists favour a classification in which the order Acarina is divided into three suborders, namely, Sarcoptiformis with its supercohorts Oribatei and Acaridiae; Trombidiformes with its super-cohorts Tarsonemini, Stomostostigmata, and Prostigmata; and Parasitiformes with its supercohorts Ixodides (ticks) and Mesostigmata.

Those of veterinary interest together with their pertinent superfamilies are differentiated in the following key:

KEY TO THE SUB-ORDERS AND SUPERFAMILIES OF ACARINA CONTAINING SPECIES ASSOCIATED WITH LIVESTOCK IN AUSTRALIA

1. Tracheae absent.. 2
   Tracheae present.. 3
2. Body vermiform; legs rudimentary, composed of only three joints; parasitic in the hair follicles of mammals.........BRACHYPODA (Demodicoidea)
   Body not vermiform; legs composed of more than three joints..ASTIGMATA (Sarcoptoidea)
3. Tracheae opening at or near the bases of the chelicerae; adults frequently free-living and larvae only parasitic...........PROSTIGMATA (Trombidoidea)
   Tracheae not opening at or near the bases of the chelicerae................. 4
4. Cephalothorax separated from abdomen by a suture; a pair of pseudostigmata at postero-lateral corners of cephalothorax; hard-bodied, free-living mites..CRYPTOSTIGMATA (Oribatoidea)
   Cephalothorax and abdomen without any suture................................ 5
5. Spiracles opening laterally on the sides of the body, either behind the fourth pair of legs or between the third and fourth pairs......MESOSTIGMATA 6
   Spiracles, if present, opening ventrally; abdomen usually segmented..HETEROSTIGMATA (Tarsonemoidea)
6. Hypostome small or absent, never with recurved teeth; tracheae usually opening through chitinous tubes or peritremes; sternal plate usually present... ... ...Parasitoidea
   Hypostome large and provided with recurved teeth; tracheae opening through a chitinous plate; sternal plate usually absent...........Ixodoidea

The superfamily Ixodoidea contains the ticks. The mites are distributed in the other superfamilies.

MITES

Variable in structure and size, usually minute, with a capitulum that carries the mouth-parts and articulates with the body; mouth-parts consisting of a pair of mandibles or chelicerae, a pair of jointed palpi, and a median, unarmed hypostome; usually no demarcation between cephalothorax and abdomen; legs usually six-jointed, attached to cephalothorax; respiration by tracheae or by general surface of the body; alimentary canal consisting of a buccal cavity, a pharynx with a pumping function, an oesophagus, a midgut with a bifurcated diverticulum, and a hindgut terminating in a rectum that receives the Malpighian tubes.

Habits and Life History. The great majority of mites are free-living. Many species are injurious to plants, some are predacious, and others are parasitic on invertebrates and vertebrates, both terrestrial and aquatic. The species parasitic on mammals are found either on or just beneath the skin; a few forms are truly endoparasitic in various tissues and passages within the body. Some species infest the fur and feathers and rarely come into contact with the skin.

Mites may be oviparous or ovoviviparous. The larva, on hatching from the egg, has only three pairs of legs. It feeds and moults to form the first-stage nymph. This is usually followed by another nymphal stage, in which the nymphs resemble the adult in having four pairs of legs, but are not sexually mature. The second-stage nymph moults to the sexually mature male or female. In some species the sexually mature female is known as the pubescent female, which after copulation with the male moults again to the ovigerous female.

Importance. The truly parasitic species live by piercing the tissues and sucking up blood and fluids. This causes considerable irritation. In the family Sarcoptidae infestation results in a thickened, scabby condition of the skin known as mange.

Mites may also be vectors of disease, such as typhus fever of man and spirochaetosis of poultry. One species is the intermediate host of a roundworm. The oribatid mites are intermediate hosts of a family of tapeworms infesting ruminants, equines, rabbits, and certain primates.

Superfamily PARASITOIDEA

Blood-sucking mites with chelicerae modified into piercing structures, sometimes shear-like; no demarcation between cephalothorax and abdomen; body with a number of chitinous plates; tracheae opening laterally at the sides of the body through chitinous tubes or peritremes; first pair of legs usually slender and used as feelers.

Five species of Parasitoidea are important parasites of livestock, namely, the poultry red mite, *Dermanyssus gallinae* (Redi.) (p. 163), the tropical fowl mite, *Liponyssus bursa* Berlèse (p. 165), the northern fowl mite, *L. sylviarum* Canes., the cattle ear-mite, *Raillietia auris* (Trouessart), and the dog nose-mite, *Pneumonyssus caninum* Chandler and Rühe. *D. gallinae*, *Pneumonyssus caninum* and *L. bursa* are recorded from Australia. In the female, *L. bursa* has an egg-shaped anal plate (Fig. 103) and chelicerae that are shear-like with both arms movable (Fig. 100 (*a*)); whereas in *D. gallinae* the anal plate is broadest anteriorly (Fig. 102) and the chelicerae are needle-like (Fig. 100 (*b*)). *L. sylviarum* is confined to temperate climates such as Canada and Great Gritain, *R. auris* is found only in Europe, and *P. caninum* occurs in the United States as well as in Australia.

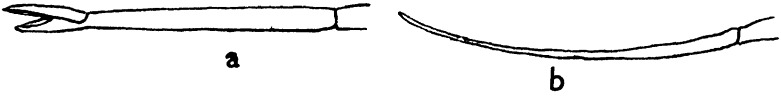

Fig. 100. Chelicerae of (*a*) *Lipcnyssus*; (*b*) *Dermanyssus.*
(*After Bedford.*)

Another species, *B. dellonyssus bacoti* (Hirst) is a common and widely distributed parasite of rats, which will sometimes attack man. This species is a true intermediate host of a roundworm parasite, *Litomosoides carinii*, which infests the cotton rat in North America.

Superfamily TROMBIDOIDEA

Tracheae opening anteriorly at or near the bases of the chelicerae; the last palpal segment modified into a thumb-like structure, opposing a claw-like extension of the antepenultimate segment.

This superfamily includes the harvest or scrub itch-mites, which are parasitic only in the larval stage (p. 166), *Syringophillus columbae* Hirst and *S. bipectinatus* (Heller) (p. 171), elongate mites found in the quills of domestic birds, and *Psorergates musculi* Tyrrell and *P. ovis* Womersley (p. 171), which infest the skin of the mouse and sheep respectively. Other species of this superfamily are predacious and may be found preying on other species of mites infesting animals and birds.

Superfamily TARSONEMOIDEA

Mouth-parts situated in a head-like structure; female abdomen distinctly segmented and greatly distended at the tip during pregnancy.

Pediculoides ventricosus Newport, the grain or hay itch-mite, is widely distributed throughout the world and is well known in Australia. It is usually parasitic on the larvae of certain insects, for example, grain weevils and grain moths, and, for this reason is frequently found in great numbers in hay. Men and animals in contact with infested hay and other stored dry products may be attacked and suffer severe irritation. It may also be serious among bees.

Superfamily SARCOPTOIDEA

Mouth-parts degenerate and the palpi more or less fused with the rostrum; skin showing fine parallel folds; legs short and frequently ending in suckers.

Here are included the poultry feather mites and the mange-mites of livestock and man.

KEY TO THE SPECIES OF SARCOPTOIDEA RECORDED FROM AUSTRALIA

1. Body strongly depressed; sexual dimorphism sometimes very strongly pronounced; feather mites of poultry.......... 9
   Body rarely strongly depressed; soft-bodied mites; not living on or in the feathers of birds.......... 2
2. Vulva longitudinal; mouth-parts fused to form a sucking tube; parasitic in the tissues of birds.......... 3
   Vulva transverse; mouth-parts free; parasitic on or in the skin of mammals and birds.......... 4
3. Body elongate with a suture between cephalothorax and abdomen; parasitic in the subcutaneous tissues of fowls...*Laminosioptes cysticola* (p. 174)
   Body oval with no demarcation between cephalothorax and abdomen; parasitic in respiratory passages, air-sacs, and elsewhere in body of the fowl .... *Cytoleichus nudus* (p. 173)
4. Small species; legs III and IV not or barely projecting beyond the margin of the body; male without posterior lobes and anal suckers on the abdomen. 5
   Larger species; legs III and IV of females and immature stages projecting beyond the margin of the body; in the male, legs IV much shorter than legs III; male with posterior lobes and suckers on the abdomen.......... 7

5. Anal opening dorsal; tarsal suckers on legs I and II of females and legs I, II, and IV of male; on cats and sometimes dogs...*Notoedres cati* (p. 186)

Anal opening terminal.......... 6

6. Tarsal suckers absent on all legs of females, present on all legs of males; female with a pair of longitudinal chitinous bars on the dorsum in front; on fowls—

(*a*) on legs.......... *Cnemidocoptes mutans* (p. 176)

(*b*) at base of feathers.......... *C. gallinae* (p. 175)

Tarsal suckers present on legs I and II of female and legs I, II, and IV of male; longitudinal bars absent on dorsum of female, dorsum with sharp-pointed scales and rod-like setae—

(*a*) on pig.......... *Sarcoptes scabiei* var. *suis* (p. 179)

(*b*) on dog.......... *S. scabiei* var. *canis* (p. 179)

(*c*) on camel..........*S. scabiei* var. *cameli*

7. Tarsal suckers on a short, unsegmented peduncle.......... 8

Tarsal suckers on a long, three-segmented peduncle—

(*a*) on goat (ears).......... *Psoroptes caprae* (p. 184)

(*b*) on horse (ears).......... *P. hippotis* (p. 183)

8. Tarsal suckers on legs I, II, and IV of female; posterior lobes of male well developed with spatulate setae on posterior margins—

(*a*) on horse.......... *Chorioptes equi* (p. 186)

(*b*) on ox.......... *C. bovis* (p. 186)

(*c*) on sheep.......... *C. ovis* (p. 186)

Tarsal suckers only on legs I and II of female; posterior lobes of male much less salient, the hairs not spatulate; ear-mite of dog and sometimes cats.......... *Otodectes cynotis* (p. 187)

9. On pigeons.......... *Faculifer rostrata* (p. 173)

On fowls.......... 10

10. Body short and circular; integument weakly chitinized; living on the skin .... *Rivoltasia bifurcata* (p. 173)

Body more elongate; integument strongly chitinized; males with legs III and IV strongly developed; anal sucker well developed, living on the feathers..........*Megninia cubitalis* (p. 173)

Superfamily DEMODICOIDEA

Minute worm-like mites with degenerate mouth-parts, three-jointed legs, and an elongate, annulated abdomen; eyes and anus absent; parasitic in the sebaceous glands and hair follicles of man and many animals.

There is only a single genus, *Demodex*, in this superfamily.

Superfamily ORIBATOIDEA

Hard-bodied, free-living mites with a distinct suture between cephalothorax and abdomen; a pair of pseudostigmatic organs at the posterolateral corners of the cephalothorax.

Commonly known as beetle mites, species of Oribatoidea are very prevalent in pastures, particularly in damp areas. They are intermediate hosts of species of anoplocephalide tapeworms, which infest certain primates, the rabbit, equines, and ruminants (Fig. 101). Investigations in the U.S.S.R. and the United States show that species of *Galumna, Allogalumna, Scheloribates, Oribatula*, and *Peloribates* are intermediate hosts of *Cittotaenia denticulata* of rabbits, *Anoplocephala perfoliata, A. magna* and *Paranoplocephala mamillana* of equines, and *Moniezia expansa, M. benedeni*, and *Thysaniezia giardi* of sheep, cattle, and goats.

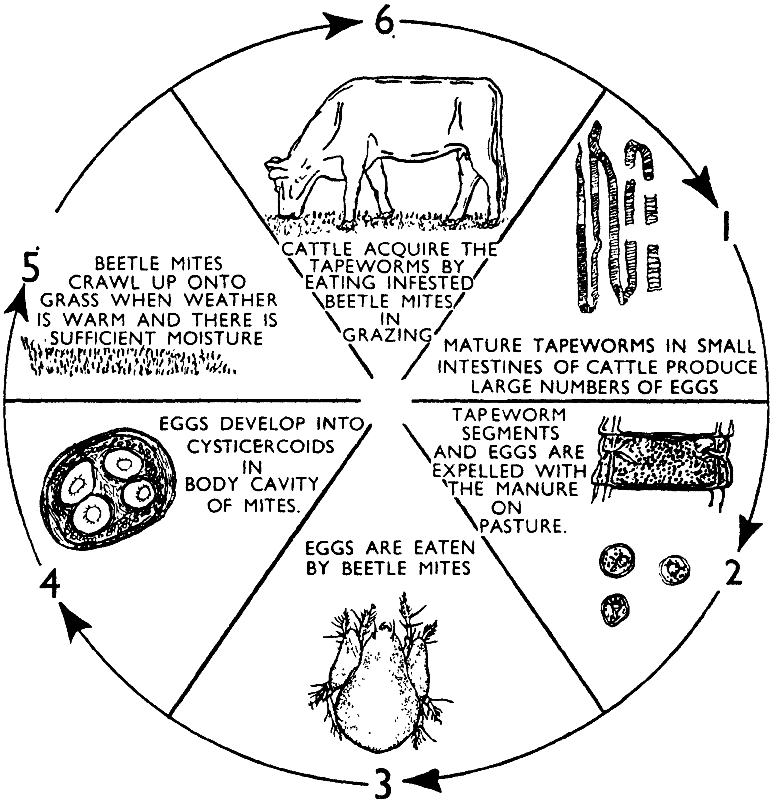
6
1
MATURE TAPEWORMS IN SMALL INTESTINES OF CATTLE PRODUCE LARGE NUMBERS OF EGGS
2
TAPEWORM SEGMENTS AND EGGS ARE EXPELLED WITH THE MANURE ON PASTURE.
3
EGGS ARE EATEN BY BEETLE MITES
4
EGGS DEVELOP INTO CYSTICERCOIDS IN BODY CAVITY OF MITES.
5
BEETLE MITES CRAWL UP ONTO GRASS WHEN WEATHER IS WARM AND THERE IS SUFFICIENT MOISTURE
CATTLE ACQUIRE THE TAPEWORMS BY EATING INFESTED BEETLE MITES IN GRAZING

Fig. 101. The life cycle of *Moniezia expansa*, a tapeworm of ruminants, for which species of oribatid mites are intermediate hosts.

(*After Dikmans.*)

Scutovertex minutus is a vector of *Moniezia* of sheep in Scotland. These equine and ruminant tapeworms are common in Australia, but their mite intermediate hosts are not known.

IMPORTANT SPECIES OF MITES

The Poultry Red Mite (*Dermanyssus gallinae* **(Redi)**). This is a widespread and common blood-sucking pest of poultry of all kinds. It will also attack caged birds and wild birds such as sparrows, pigeons, and starlings, and will attempt to feed on man and animals. In Australia it is recorded from all States, but is not a common parasite in subtropical and tropical areas. The red mite is a small species, about 1·5 millimetres in length (Fig. 102). Unfed specimens are greyish, but after a meal of blood the mites assume a reddish colour.

Habits and Life History. D. gallinae is chiefly nocturnal in habit, hiding away in sheltered places during the day and feeding at night. Mites, however, may be seen in small numbers on birds during the day if the infestation in the poultry-house is very heavy. Sitting hens may also be attacked during the day.

The female mite deposits three to seven eggs on the day after feeding. These are laid in the sheltered places in which the mites hide, as many as thirty-two eggs or more being laid by the female during her lifetime. The eggs are pearly-white in colour, and in warm weather they hatch in about two days. The larvae do not feed, and one to two days after hatching they moult to the first nymphal stage. This stage feeds and moults to the second nymphal stage one to two days later. The second nymphal stage feeds and moults to the adult in another one to two days, the life cycle in warm weather being completed in seven days. During the winter development is considerably retarded. The mites are able to survive from four to five months in empty poultry-houses during the summer and even longer in winter.

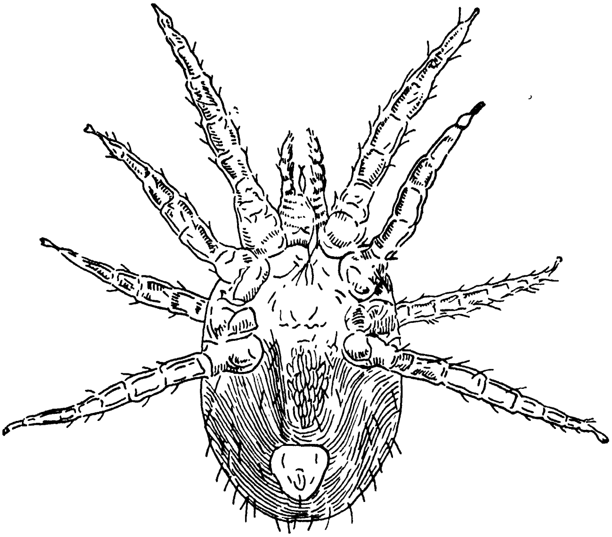

Fig. 102. The poultry red mite, *Dermanyssus gallinae* (ventral view). (*After Helmsing.*)

Importance. The loss of blood and the irritation caused by infestation is associated with loss of condition and decreased egg production. Red mite infestation is most serious among young birds and setting hens. Caged birds may be killed. This parasite is capable of transmitting spirochaetosis or fowl tick fever (*Borrelia anserina*), fowl-pox, and possibly leucosis.

The mites can also be a very irritating pest of man, who may be attacked when in contact with infested poultry, or when mites are carried into dwellings by birds such as sparrows and pigeons. Animals quartered near infested poultry-houses may also be attacked.

The red mite is a potential vector of the virus of St Louis encephalomyelitis of man in the United States.

Control. For effective control the first essential is the removal and destruction of all rubbish and nesting straw. The building is then thoroughly sprayed with kerosene, fuel oil, or creosote, the spray being applied under pressure in order to penetrate all cracks and crevices in which the mites shelter. The spraying should be done early in the day to give the material a chance to soak in before the birds go to roost. Good results have been reported from DDT, with concentrations of 0·5 to 1·0 per cent. BHC (0·25 per cent gamma isomer) appears more efficient. Chlordane (0·25 per cent) will also control the mites. As mentioned previously (p. 92), both DDT and BHC, however, may cause egg and carcass taint.

The Tropical Poultry Mite (*Liponyssus bursa* **Berlèse).** This fowl-mite (Fig. 103) is similar in appearance to *D. gallinae*, but is smaller, and without the "waist" so frequently seen in the latter species. It can also be distinguished from *D. gallinae* by the characters of the chelicerae and anal plate (p. 160). It is essentially a parasite of tropical and subtropical areas though it has been recorded from New Zealand. In Queensland *L. bursa* is the common blood-sucking mite of poultry.

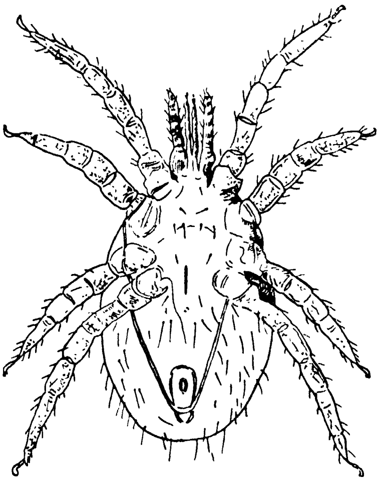

Fig. 103. The tropical poultry mite, *Liponyssus bursa* (ventral view.) (*After Helmsing.*)

Habits and Life History. L. bursa will attack poultry, caged birds, various wild birds such as the sparrow and starling, domestic animals such as the horse, and also man. It may be found on birds at any time of the day or night, congregating in greatest numbers in the region of the tail and below the vent. In heavy infestations mites may also be seen among the nests and sometimes on the perches.

The entire life cycle is usually passed on the host. The eggs are laid among the feathers, sometimes in the nest boxes. Hatching occurs in two to three days. The newly hatched larva does not feed, but in about seventeen hours moults to the first nymphal stage. There are two nymphal stages, both of one to two days' duration, each stage feeding before moulting. The duration of the life cycle is about the same as for *D. gallinae*.

Importance. The tropical fowl-mite, owing to its closer association with poultry, is probably a more serious parasite than the red mite. Birds lose condition, egg production declines, and among young birds and small caged birds infestation may be fatal. Like the red mite also, it is a not uncommon pest of man, and in Queensland this is the species usually concerned in infestation of dwellings. It is introduced by sparrows and pigeons, and while these birds are nesting it is content to remain in the vicinity of the nests, feeding on the nesting hens and the young birds. Once nesting is finished, the mites commence to wander in search of food, and they can be very irritating to the people occupying the infested dwellings. Wild birds probably play an important part in the spread of these mites.

L. bursa has not been incriminated as a vector of any of the diseases carried by *D. gallinae*. In the United States the virus of equine encephalomyelitis has been found in this parasite and in *L. sylviarum*.

Control. Since the mites remain on the birds most of the time, it is necessary to treat the birds with some insecticide as well as giving attention to the poultry-house. The poultry-house is treated in a manner similar to that recommended for the control of red mite. The birds themselves are dipped in 2 ounces of very fine sulphur and 1 ounce of soap per gallon of water, as for lice (p. 92). Alternative treatments, where dipping is not advisable, are (*a*) dusting the birds thoroughly with very fine sulphur; (*b*) painting nicotine sulphate on the perches as for lice (p. 92); or (*c*) applying equal parts of naphthalene and paradichlorobenzene to the tail and vent and over the perches.

Scrub Itch-mites. These mites are parasitic only in the larval stage, the adults and nymphs being free-living in the soil and probably feeding on the eggs and immature stages of small arthropods. The adults are the largest mites known and measure up to 2·5 millimetres. They are covered with bristles or feathered hairs, which give the mites a bright velvety-red colour (Fig. 104).

The tiny larvae measure only 0·2 millimetre, and attach in clusters to many vertebrates, including domestic animals, poultry, and man. They feed on lymph, which they obtain by forcing the chelicerae into the skin. A remarkable structure, a feeding tube (Fig. 105), is formed in the host tissues around the chelicerae, but the origin of the structure is obscure. These parasites are known throughout the world, and infestation is followed by severe irritation. In Europe they are called harvest mites, in North America chiggers, in New Guinea mokkas, and in Australia scrub itch-mites. The best-known species in Europe is *Trombicula autumnalis* Shaw, and in North America *T. alfreddugesi* Ouds.

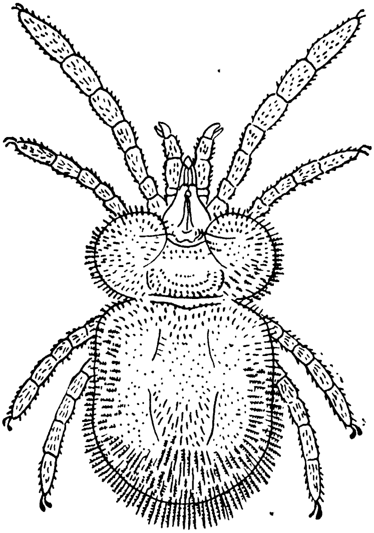

Fig. 104. An adult trombiculid mite.

(*After Ewing.*)

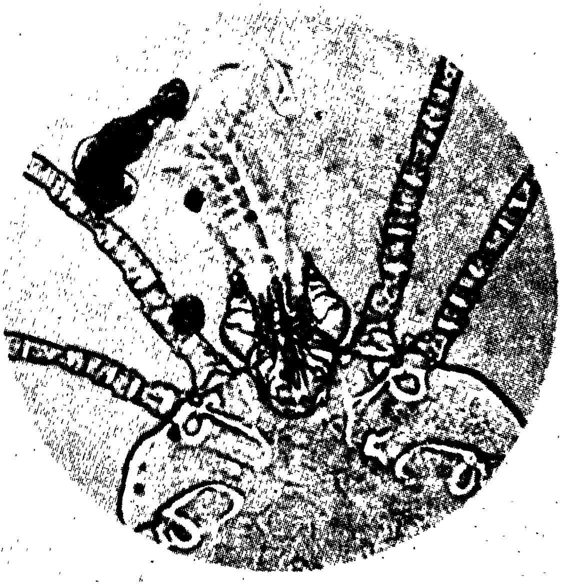

Fig. 105. Larva of *Trombicula sarcina* with feeding tube, eighteen hours after attachment.

(*After Gill, Moule, and Rick.*)

Several species are known in Australia, mainly through their association with man. *T. minor* Berlèse is the cause of scrub itch in North Queensland, whilst black-soil itch in the central part of this State is due to *T. sarcina* Womersley (p. 168), which is also associated with leg itch in sheep. Grass itch in New South Wales and southern Queensland is due to infestation with *Leeuwenhoekia australiensis* (Hirst), which may also occur in the ears of cats, and on the breast, under the wings, and on the neck and face of chickens. On young chicks infestation may be fatal. Tea-tree itch in South Australia is caused by *T. samboni* Hirst, which also attacks cattle, horses, and sheep, and may cause severe irritation.

Scrub itch-mites are extremely important parasites of man, for certain species are vectors of mite or scrub typhus. Tsutsugamushi or Japanese River fever (*Rickettsia orientalis*), which is identical with Malayan scrub typhus and also with scrub typhus of New Guinea and North Queensland, is carried by *T. akamushi* (Brumpt) in Japan, and by *T. deliensis* Walch in New Guinea, Malaya, and India. The vector in North Queensland is not known.

Control. In man, infestation is prevented by smearing the socks and clothing with dibutylphthalate, which is a highly efficient and very lasting miticide. Animals and birds may be treated with 0·5 per cent

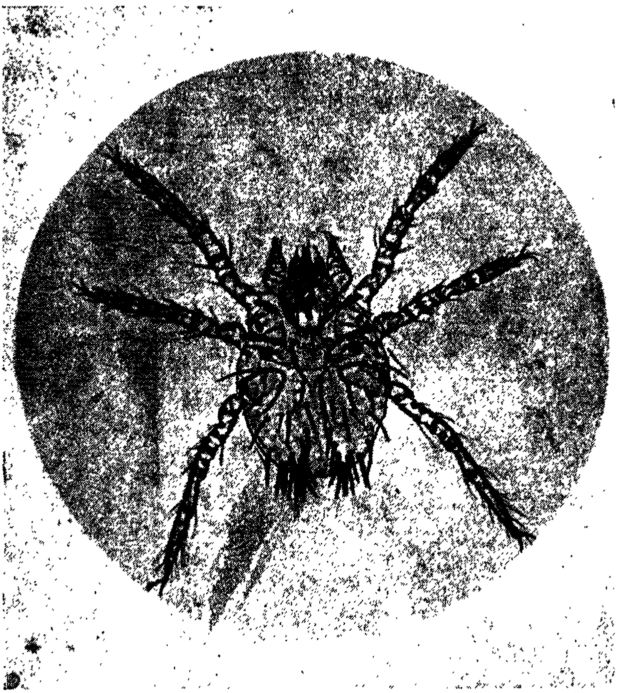

Fig. 106. The leg itch-mite of sheep, *Trombicula sarcina* (ventral view). *(After Gill, Moule, and Rick.)*

gamma BHC as a dust, or 0·1 per cent as wash. Finely divided sulphur is said to be effective. Keeping the vegetation cut close will assist in controlling infestations in poultry yards and elsewhere. Dusting with BHC at the rate of 1 to 1½ pounds per acre is very beneficial.

Trombidiosis or Leg Itch of Sheep (*Trombicula sarcina* **Womersley).** This condition is due to infestation with *Trombicula sarcina* (Fig. 106). The tiny species of mite is associated with the true black earths of central Queensland, and its distribution extends over an area forty to fifty miles wide, from about thirty miles north of Clermont southwards to Springsure and Rolleston. It also occurs in the Narrabri district, New South Wales.

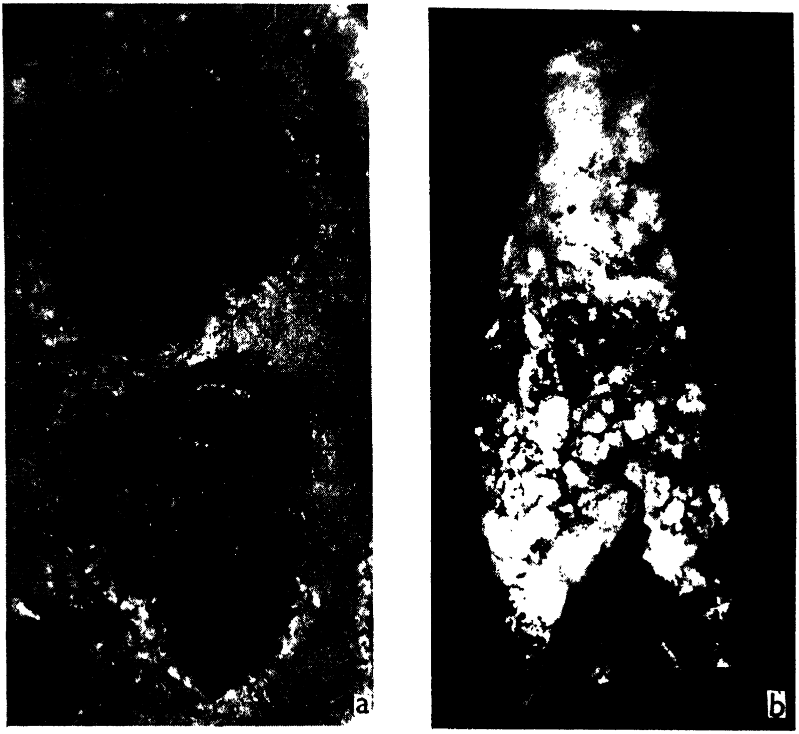

Fig. 107. Lesions on leg of sheep caused by *Trombicula sarcina.* (*a*) Early lesions; (*b*) advanced lesions.
(*After Gill, Moule, and Rick.*)

The known hosts include man, sheep, dogs, grey kangaroo, and occasionally wild birds. The grey kangaroo is regarded as the principal natural host.

Importance. The mites are most prevalent after the summer rains, when sheep may be severely attacked irrespective of age and sex. The skin between the accessory digits is most favoured by the mites, which attach in clusters about 1 millimetre in diameter. They are fully engorged in three to five days, and as engorgement proceeds the cluster appears as a small yellow-golden centre in a raised weal.

When first exposed to attack, sheep stamp their feet and bite their legs, and the skin of the heels, coronet, and pastern becomes reddened

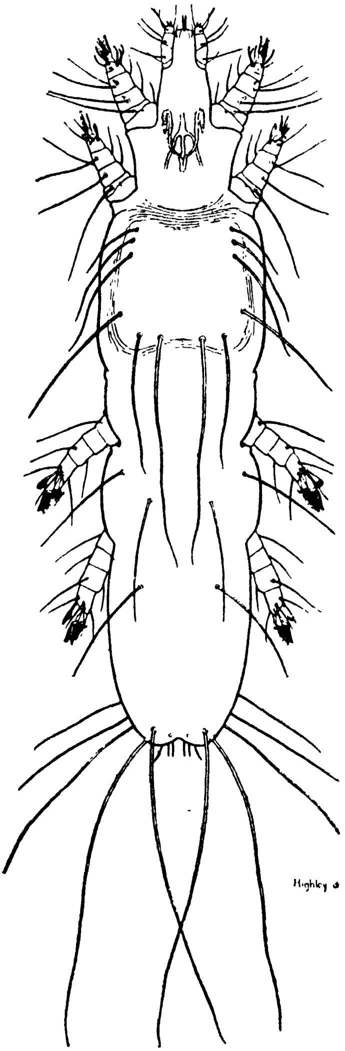

Fig. 108. The poultry quill mite, *Syringophillus bipectinatus.*

(*After Hirst.*)

and broken (Fig. 107(*a*)). Secondary infection occurs and the skin over the whole of the shanks and fetlocks becomes thickened, tough, and scabby, with exuding pus (Fig. 107(*b*)). The affected area may sometimes extend into the parts covered with wool.

Control. Very little attention has been given to control, but good results should follow from a shallow bath, just covering the affected areas, of 0·1 per cent gamma BHC or 1 per cent polysulphide lime sulphur. Untreated sheep may take several weeks to recover.

Mites in long-standing cases are difficult to detect and prolonged search of material from lesions may be necessary, following maceration in caustic potash and clearing in lactophenol.

The Poultry-quill Mites (*Syringophilus bipectinatus* **(Heller)** and *S. columbae* **Hirst).** In this genus the body is greatly elongated and the legs are provided with brush-like pulvilli. The mites occur inside the quills of the domestic fowl and pigeon. *S. columbae* is recorded from Australia, being found in the quills of fowls in New South Wales. *S. bipectinatus* (Fig. 108) is described in the United States as being responsible for a peculiar moult in fowls, which leaves behind only the stumps of the feathers. These two names may refer to only one species.

The Itch-mite of Sheep (*Psorergates ovis* **Womersley).** This is a very minute species, 167 to 189μ in length, almost spherical in appearance, and bearing a general resemblance to the sarcoptic mange-mites. The stumpy legs, however, are without suckers and the penis of the male is situated dorsally on the cephalothorax. The female has two pairs of long setae arising ventrally from a pair of lobes, while the male has one pair arising ventrally from a median tubercle (Fig. 109). The itch-mite is

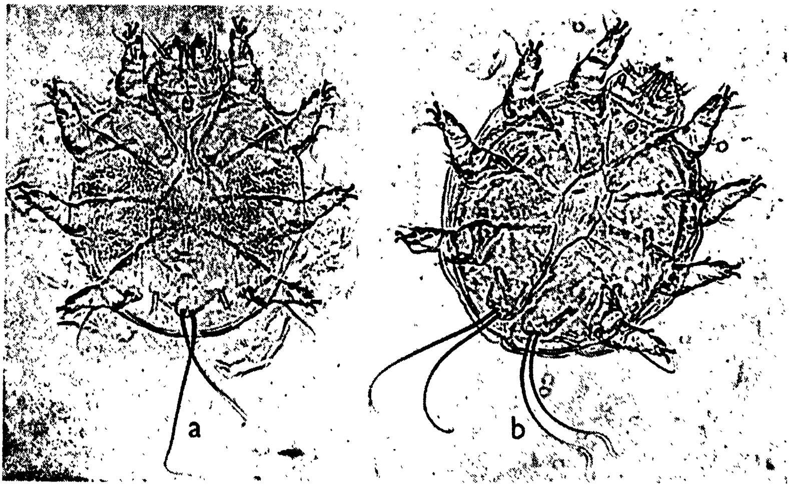

Fig. 109. The itch-mite of sheep, *Psorergates ovis.* (*a*) Male (ventral view), showing dorsal penis; (*b*) female (ventral view).

(*After Carter.*)

confined to merino sheep in Australia, and was first reported in 1940. It is now known from all States.

The life cycle is unknown.

Importance. The mites burrow into the skin, setting up a condition of irritation. Infested animals bite and scratch themselves vigorously, and the fleece eventually becomes ragged and torn, with tassels of tangled wool hanging from the sides and thighs, a condition resembling heavy lice infestation (Fig. 110). The staple is inclined to be stringy, with a pointed tip, and it quickly loses its strength.

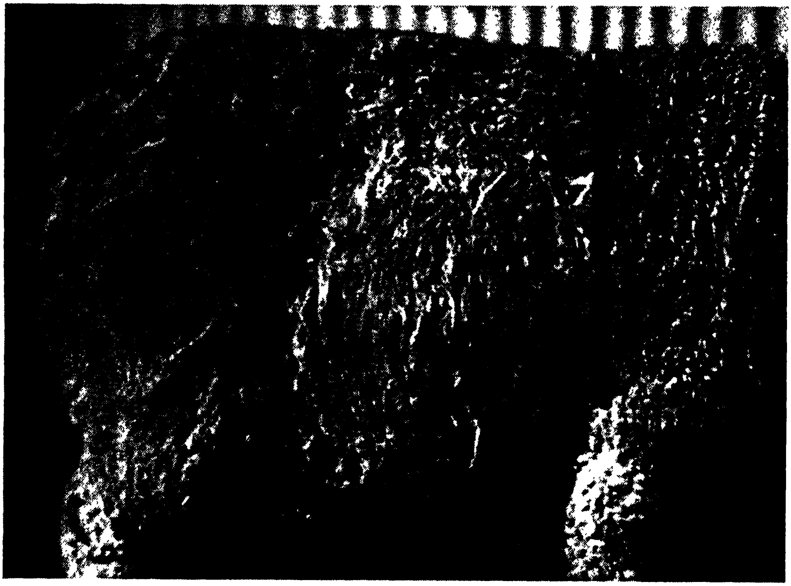

Fig. 110. Damage to fleece caused by *Psorergates ovis*.
(After Carter.)

The affected skin, usually on the sides, flanks, and thighs, is leaden in hue, with pale patches, and is covered with an accumulation of scurf. The small wrinkles of the skin may become thin and hard, sometimes with crusts on the crests.

Sheep of any age may be affected, but since the disease spreads slowly it is seen mostly in the older animals. It may take three to four years for the greater part of the body to become involved.

Control. Treatment of the entire flock in lime sulphur with a concentration of 1 per cent polysulphide sulphur is effective. Proprietory preparations usually contain 20 or 25 per cent active polysulphide sulphur, a dilution of 5 or 4 gallons respectively per 100 gallons of water being required. For thorough wetting, which is essential, 6 ounces of Agral 2 are added to each 100 gallons of diluted dip. BHC is not very effective.

Feather Mites of Poultry. These mites are found either on or in the feathers. The special nymph of certain forms (*Faculifer*) penetrates into the subcutaneous tissues of the pigeon and other birds. The more common species include *Megninia cubitalis* (Mégnin) (Fig. 111), *M. gallinula* Buch., and *Pterolichus obstrusus* Robin from the feathers of the fowl; *Dermoglyphus minor* Nörner and *D. elongatus* Mégnin from inside the quills of the fowl and turkey; *Epidermoptes bilobatus* Rivolta and *Rivoltasia bifurcata* (Rivolta) on the down and skin of the fowl; and *Faculifer rostratus* (Buch.), *F. cornutus* (Trouessart), *Analges bifidus* (Nitzsch), *M. columbae* Buch., and *Pterophagus strictus* Mégnin on the feathers of the pigeon. *Freyana chanayi* Trouessart is seen on turkeys. The species recorded from Australia are *M. cubitalis* and *R. bifurcata* from the fowl, and *F. rostratus* from the pigeon.

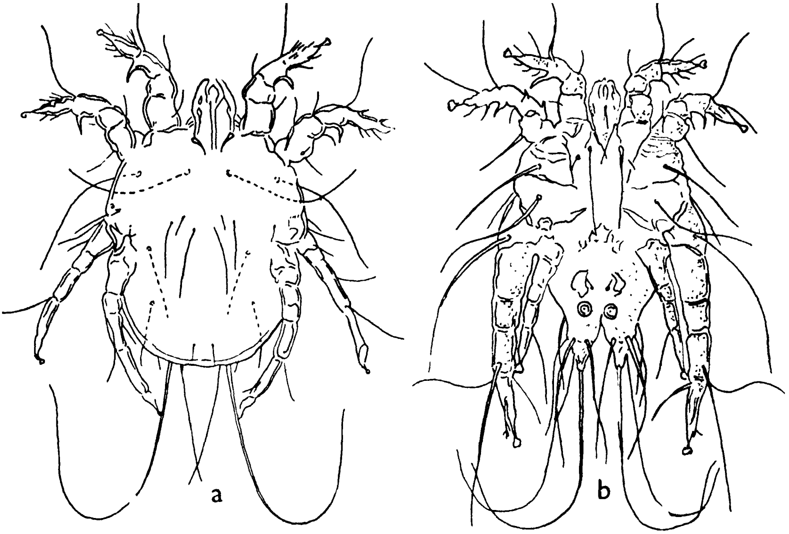

Fig. 111. A poultry feather mite, *Megninia cubitalis.* (*a*) Female (ventral view); (*b*) male (ventral view).

(*After Helmsing.*)

Importance. As a rule these mites are of little importance, but heavy infestation may occasionally be associated with a condition resembling that caused by the depluming mite, *Cnemidocoptes gallinae. M. columbae*, *E. bilobatus*, and *R. bifurcata* have all been reported as causing an itch resulting in broken feathers and loss of plumage.

Control. The control measures recommended for the poultry depluming mite, *Cnemidocoptes gallinae*, are effective against feather mites. See p. 175.

The Poultry Air-sac Mite (*Cytoleichus nudus* (**Vizioli**)). This species occurs in the respiratory passages, air-sacs and other cavities, and in the bones, kidneys, and other internal organs of the fowl, turkey, and pheasant.

It is a stout-bodied mite, with the legs ending in small suckers (Fig. 112). As a rule it is not considered of any importance, but in some quarters it is believed to predispose to pneumonia and pulmonary tuberculosis. Two cases are recorded where the mites had caused death by penetrating the pericardium and gall bladder. The life cycle is unknown. It is present, in the fowl in Australia, but is not regarded as common, and is recorded from Queensland, New South Wales, Victoria, and Tasmania.

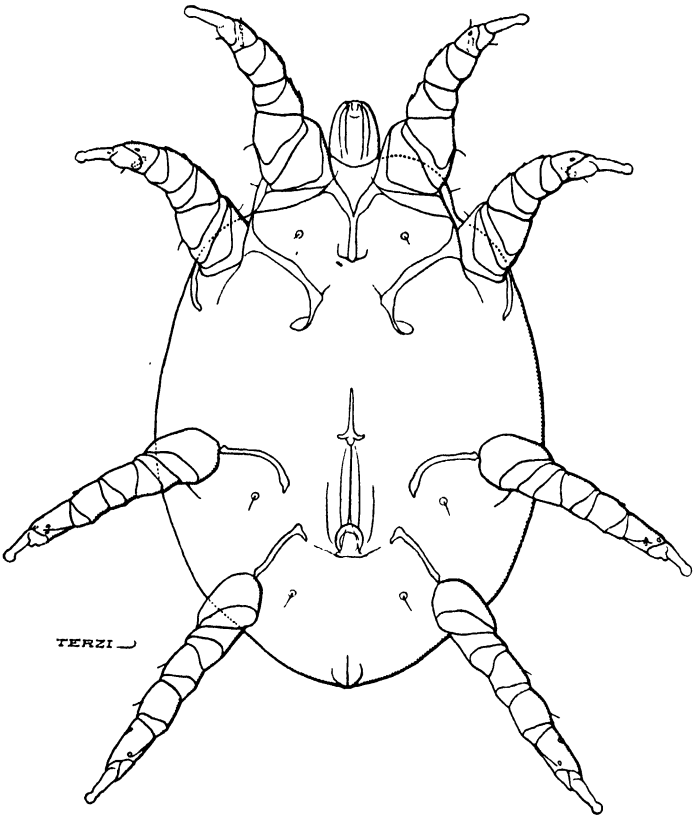

Fig. 112. The poultry air-sac mite, *Cytoleichus nudus*, female (ventral view). (*After Hirst.*)

The Poultry Subcutaneous Mite (*Laminosioptes cysticola* **(Vizioli)**). This is an elongate species with a suture between the cephalothorax and abdomen (Fig. 113). Since this mite occurs in the subcutaneous tissues of the domestic fowl it is detected only on dissection. Its presence is diagnosed by the appearance of minute cysts in the subcutis, resembling bits of fat. These cysts contain dead mites, the live ones being in the tissues. The life history in unknown.

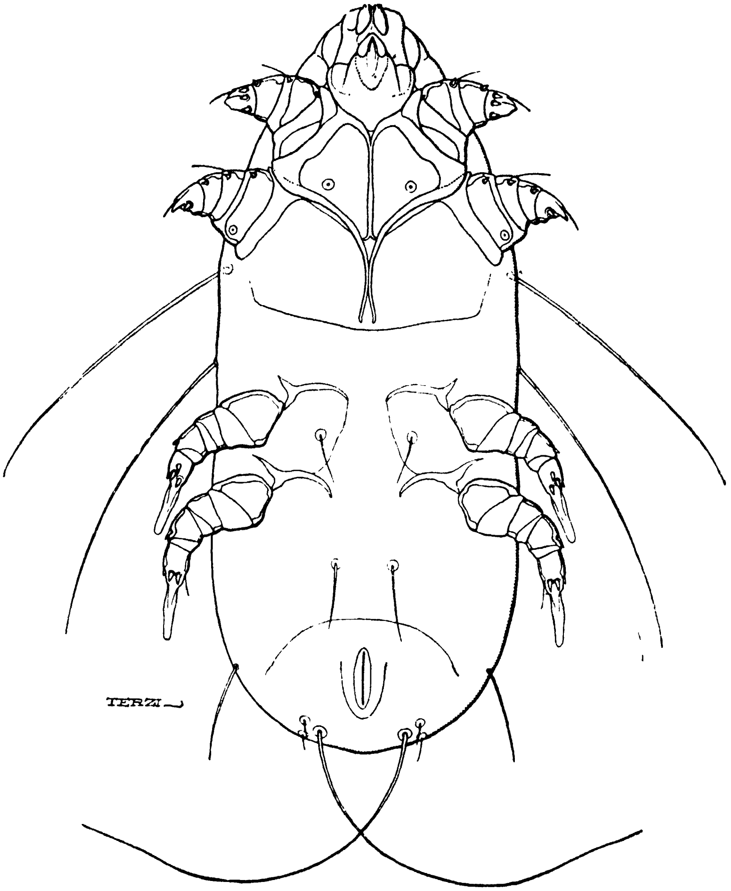

Fig. 113. The poultry subcutaneous mite, *Laminosioptes cysticola*, female (ventral view).

(*After Hirst.*)

The subcutaneous mite has been seen in all Australian States except South and Western Australia. It is considered to possess only a low degree of pathogenicity.

The Poultry Depluming Mite (*Cnemidocoptes gallinae* **(Railliet)).** This mite is usually found in the follicles at the base of the feathers, particularly on the back and sides. It burrows into the skin at the base of the feathers and the irritation causes the bird to pick at them, causing them to break or to be pulled out. The mites are extremely minute, but they may be detected by examining the detritus on the quills of feathers pulled from the affected area.

C. laevis (Railliet) causes depluming itch or scabies in the pigeon, but is not recorded from Australia.

Control. The most effective treatment is a sulphur dip of 2 ounces of finely divided sulphur and 1 ounce of soap to 1 gallon of water.

The Poultry Scaly-leg Mite (*Cnemidocoptes mutans* **(Robin))**. Scaly-leg, the term given to the condition caused by this mite, is found in the domestic fowl, turkey, guinea fowl, and pheasant. The tiny mites (Fig. 114) attack the skin of the legs under the scales, causing an inflammation with an exudate, eventually giving rise to a marked, irregular thickening of a scaly nature (Fig. 115). When nothing is done to check the infestation, malformation and lameness may occur. Occasionally the comb, wattles, and neck may be attacked.

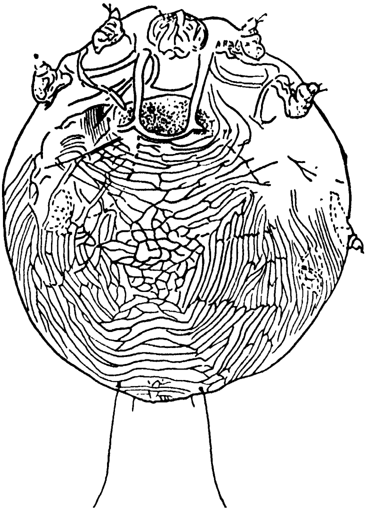

Fig. 114. The poultry scaly-leg mite, *Cnemidocoptes mutans* (ventral view). (*After Helmsing.*)

Control. The mites are spread mainly by contact between birds, but may also be picked up from the perches. These should be sprayed or painted with creosote, fuel oil, or kerosene.

The entire flock should be treated by dipping the legs up to the hock in used motor oil or fuel oil, and, where necessary, removing the thick crusts with a brush. Several treatments at 10 day intervals may be required for eradication. BHC, 0·1 per cent gamma isomer, is also effective.

Sarcoptic Mange

Sarcoptic mange is caused by tiny mites, 200 to 450μ in length, which live in galleries in the skin. The condition is also known as scabies. Man, and domestic and many wild animals—including the fox and wombat in Australia—are affected. Since the morphological differences between the mites found on these hosts are minute, each is regarded as a variety or form of *Sarcoptes scabiei.* Most of them can be transferred from one host to another, but there is some degree of host specificity, for mites will not survive as a rule, on an abnormal host for more than a few generations.

The body is almost circular. Legs III and IV are very short and hardly project beyond the body margin. The males are smaller than the females and on legs I, II, and IV have a small bell-shaped tarsal sucker on a long unsegmented pedicle. In the female these suckers, which are really flat structures like pieces of wet wash-leather, are confined to legs I and II. The dorsal surface of the body bears characteristic sharp-pointed scales and symmetrically arranged rod-like setae posteriorly (Fig. 116).

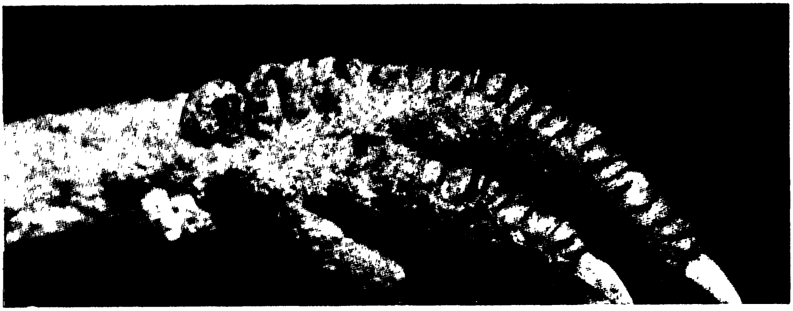

Fig. 115. Lesions caused by the poultry scaly leg mite, *Cnemidocoptes mutans.*

Life History. Infestation of a new host probably originates with an ovigerous female, which, after finding a suitable spot on the skin, burrows into the horny layer. Here she remains for the rest of her life. Successful burrows appear to be established only where the skin reaction is not very intense. Eggs are laid in the burrow at the rate of two to three daily, and may continue to be deposited at this rate for about two months. The eggs hatch in three to four days and the larvae leave the burrows and shelter in the hair follicles. Here they moult to give rise to the nymph. The nymph feeds and moults to the adult male or immature or pubescent female. After fertilization the female becomes an ovigerous female. The male is much less common than the female and constructs a short burrow, but spends most of its life wandering about in search of females. The complete life cycle, egg to ovigerous female, may be completed in ten days, though fourteen days is the average period.

Importance. In human sarcoptic mange there is great mortality among the infestation during development, and mites are relatively few. The itching and rash are considered to be the result of the development of a hypersensitivity, the production of follicular papules being an early manifestation. The damage to the skin is increased by trauma from scratching and by secondary infection by organisms, of which *Staphylococcus albus* and *S. aureus* are most common. Thus the actual dermatitis associated with scabies becomes a rather complicated condition.

It remains to be determined whether the disease in animals has a similar etiology. Mites are frequently very difficult to find, particularly on animals with advanced lesions. The disease, however, presents a similar picture irrespective of the host. Follicular papules appear, the skin becomes inflamed and swollen, and this condition is accompanied by intense itching. The affected areas exude serum, which dries and forms small crusts. The hair becomes erect and may fall out. As the disease advances the itching becomes more intense, and, as a result of the scratching and rubbing by the host, the affected area is enlarged and the skin is bruised and raw. Scabs and crusts form, which crack and exude blood and serum. The skin eventually becomes thickened and leathery and is thrown into folds. In neglected cases the whole body may be affected, and the animal becomes weak and emaciated, and may even die. Sarcoptic mange in temperate areas is more prevalent during winter, and this is ascribed to the poor condition of the host.

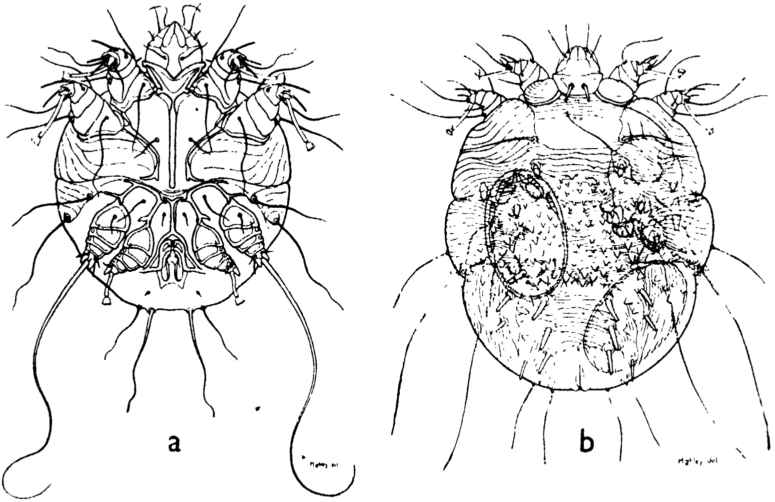

Fig. 116. The sarcoptic mange or scabies mite, *Sarcoptes scabiei* var. *equi.* (*a*) Male (ventral view); (*b*) female (dorsal view).

(*After Hirst.*)

In man, infestation is more likely to be set up by direct contact—for example, when people sleep together—than through blankets, towels, privies, and other objects used by infected persons. However, the importance of harness, brushes, curry-combs, and infested premises in the case of domestic animals has never received critical investigation, and may play a greater part in the epidemiology of the disease than similar objects do in the case of man.

In Australia sarcoptic mange is known only in pigs, camels, and dogs, and has never been seen in horses, cows, sheep, or goats.

Diagnosis. A diagnosis of sarcoptic mange results from the finding of the mites in skin-scrapings. Two points must be borne in mind: since the mites occur in the skin tissues, scrapings must be deep enough to cause the appearance of blood, and, since the parasites are frequently very scarce, the scrapings should be made from several areas on the body, those areas being selected on which the lesions appear most recent.

The area is first smeared with glycerine or some similar substance to hold the scrapings together. These may then be examined after heating in lactophenol till clear, or they may be boiled for about fifteen minutes in 5 per cent caustic potash, washed, then spun in a centrifuge in glycerine. The mites will rise to the surface and may be removed in a hanging drop.

Sarcoptic Mange in the Pig (*Sarcoptes scabiei* var. *suis* **Gerlach**). This is a very common disease in pigs and is widespread throughout Australia. It usually commences on the head, round the eyes and nose, and on the back, sides, and inner surfaces of the thighs. Mites may frequently be obtained from lesions inside the ears when no other lesions of the disease are apparent.

Control. Affected pigs are washed and scrubbed with warm soapy water to remove all dust and dirt, and crude oil or lime sulphur (1·5 per cent polysulphide sulphur) is applied either by hand or by means of a dip. Several treatments at intervals of five to six days are necessary for a cure. Crude oil requires careful use with white breeds, which may scald badly if exposed to the sun after treatment.

Recent tests in the United States and in Australia have shown that the disease can also be successfully treated with 0·25 per cent gamma BHC and with 0·25 per cent chlordane. These insecticides are sprayed over the body at pressures of up to 250 pounds, particular attention being paid to the inside of the ears. More than one treatment may be required.

Affected and in-contact animals should be isolated and the sties thoroughly cleaned and disinfected.

Sarcoptic Mange in the Dog (*Sarcoptes scabiei* var. *canis* **Gerlach**). Dogs of all ages and breeds may be affected by sarcoptic mange, the disease usually commencing as discrete papules on the elbows, hocks, chest wall, throat, abdomen, and head. In young dogs the disease occasionally takes the form of dry, bran-like scales that mat the hair together, but cause little irritation.

Control. Numerous remedies have been recommended, and of these the following appear most effective:

1. 0·1 to 0·25 per cent gamma isomer BHC, as a bath with a soft brush, or applied as a dressing in a bland oil, or as an ointment.

2. Washes of benzyl benzoate emulsion. This drug has given excellent results against human scabies, and one treatment with a 20 per cent concentration, if carefully applied, is effective. Some authorities employ a concentration of 33 per cent on dogs. It is advisable to treat only a portion of the body at any one time.

A 20 per cent emulsion may be made by heating together 200 millilitres of benzyl benzoate and 20 grammes of stearic acid until the latter is dissolved. Six millilitres of triethanolamine are mixed with 700 millilitres of water, which is then poured into the warm mixture of benzyl benzoate and stearic acid and stirred. The emulsion is then made up to 1000 millilitres by adding water.

3. Washes of 2 per cent tetraethylthiuram monosulphide (Tetmosol).

Here again it is advisable not to treat too large an area at the one time. Precautions should also be taken to prevent the dog from licking treated parts of the body.

4. Bathing in 1 per cent potassa sulphurata.
5. Washes of 0·25 per cent chlordane.

The number of treatments required depends on the degree of infestation and the thoroughness with which treatment is carried out. The intervals between treatments are governed by the health and reaction of the dog, and are usually from two to three days.

Prior to treatment for the skin condition, the animal should be thoroughly examined and any other causes of debility, such as worms, attended to. Diet, fresh air, and exercise are important. Disinfection of kennels, bedding, and rugs, etc., is required.

Sarcoptic Mange in other Domestic Animals. Scabies in horses caused by *Sarcoptes scabiei* var. *equi* Gerlach (Fig. 116) is very prevalent in most oversea countries and can be a serious disease, especially when large numbers of animals are stabled together, as they usually are during the winter. It generally commences on the head, neck, and shoulders, though if spread by infected harness it may commence wherever the harness touches the body.

Cattle scabies, *S. scabiei* var. *bovis* Robin, is important in America and Europe, the disease usually commencing on the inner surface of the thighs, beneath the neck, on the brisket, and at the root of the tail. The mites may establish themselves temporarily on man, causing milkers' itch.

Sarcoptic mites in sheep, *S. scabiei* var. *ovis* Mégnin, is of little importance, being usually confined to the head. Goat scabies, *S. scabiei* var. *caprae* Fürstenburg spreads from the head and ears. The whole body may be involved, at times seriously enough to cause death.

In camels, *S. scabiei* var. *cameli* (Linn.) is a common and serious disease, responsible for heavy losses if neglected.

Control. Lime sulphur (1·5 per cent polysulphide sulphur) is recommended. Several treatments are required at six- to ten-day intervals. The response is quicker if the animals are scrubbed before treatment to remove all crusts and dirt. For camels, crude oil or sulphur in oil is recommended.

BHC, 0·25 per cent gamma isomer, and chlordane, 0·25 per cent, should be effective. The disinfection of harness, rugs, brushes, etc., and infected premises should not be overlooked.

Psoroptic Mange or Scab

Psoroptic mites have an oval body and a long, conical rostrum. The tarsal suckers are borne on a long, three-segmented pedicle. The male has anal suckers and tarsal suckers on legs I, II, and III, and the female has tarsal suckers on legs I, II, and IV (Fig. 117).

Although morphological differences between the species infesting different animals are slight, host specificity is high, and a species normal to one host will not infest a host of another species.

Life History. The mites usually deposit their eggs on the edges of the lesions that their presence occasions. These hatch in one to three days.

The six-legged larva feeds and in two to three days moults to the nymph. The nymphal stage lasts two to four days, the smaller nymphs moulting to sexually mature males, the larger nymphs to pubescent or immature females. These females are fertilized by the male, and two to four days later they moult to the ovigerous female. The female mite lays 90 or more eggs during her lifetime of thirty to forty days. The complete life cycle averages about ten days.

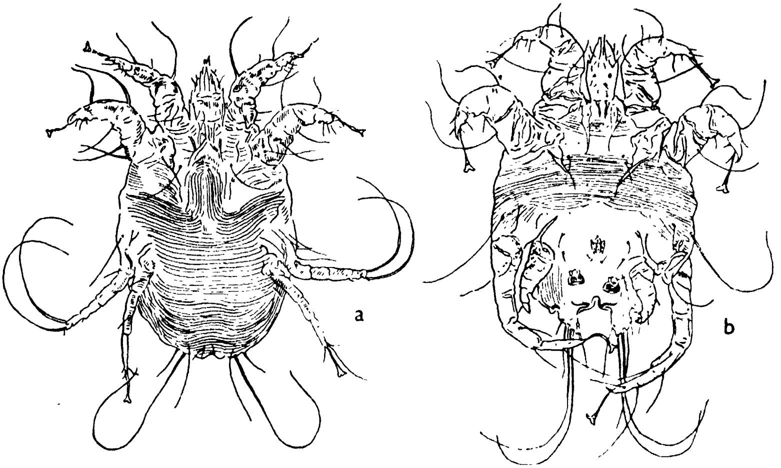

Fig. 117. The psoroptic ear mite of the goat, *Psoroptes caprae*. (*a*) Female (ventral view); (*b*) male (ventral view).

(*After Helmsing.*)

Importance. According to the species, the mites live on the skin surface, or in the external ear, and feed by puncturing the skin. The species infesting the ears cause them to become swollen, scabby, torn, and filled with wax and detritus, a condition known as psoroptic otacariasis. Infestation of the body results in psoroptic mange or scab, the first indication of which is a slight inflammation of the infested area, accompanied by itching. As the disease progresses, the itching becomes more intense and small pustules appear. These gradually become confluent and the exuding serum hardens and becomes mixed with dirt and blood to form a scab. The area is now unsuitable to the mites, which move to the more healthy skin on its margin, and so the disease gradually spreads. The itching is very marked when the animal is heated. The animal's efforts to obtain relief by biting and scratching cause further damage to the skin, which eventually becomes hardened, thickened, denuded of hair or wool, and covered with adherent crusts. In advanced cases large, bare, thickened, and scabby areas may be seen, which may crack and bleed. Affected animals rapidly lose condition and may die. The disease is seen chiefly during the winter. The Australian species of this genus are confined to the ears of the horse, goat, and rabbit.

Diagnosis. The species of mites infesting the ears may be seen by doubling back the auricula in sunlight, or by examining the secretions in the meatus. On the body, the mites are best seen by observing the edges of the lesions, preferably in sunlight. The tiny mites can be picked up on a moist needle and prepared for microscopic examination. Sometimes they are few, and skin scrapings from several areas on the edges of the lesions may be necessary. These scrapings are examined as described for sarcoptic mites (p. 178).

Psoroptic Mange in Sheep (*Psoroptes ovis* (**Hering**)). This is a serious disease among sheep (Fig. 118) in Europe, Africa, and America. It was once present also in Australia, but has not been seen in this country for more than 50 years.

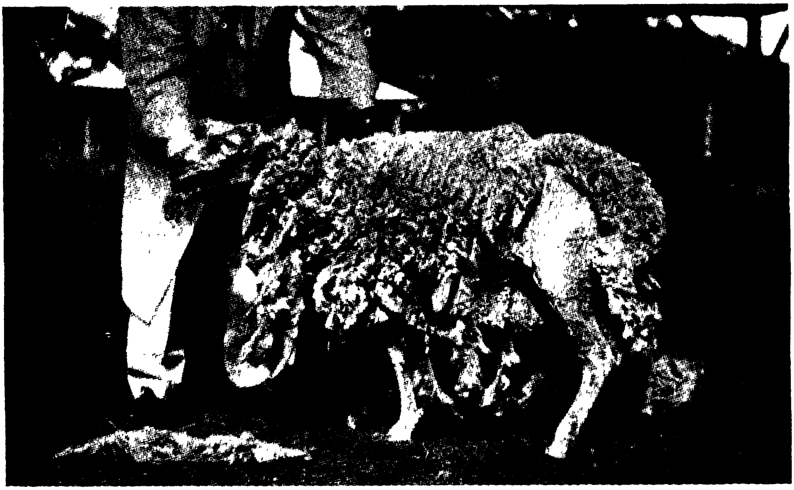

Fig. 118. A sheep severely affected with scab, *Psoroptes ovis.*

Scab was first introduced into Australia in 1788, and during the early days of colonization it was very widespread. Uncontrolled travelling of infested flocks, and the folding of sheep at night were, no doubt, responsible for this. Eradication was accomplished by rigid control of travelling sheep and systematic treatment in tobacco and sulphur dips, and, later, in lime sulphur dips. In 1866 New South Wales was declared free from scab, though in 1884 a further outbreak occurred, originating from sheep imported from the United States. On this occasion all infested and in-contact animals were slaughtered, and since then no further cases have been seen in this State. Queensland and South Australia have been free since 1866, Victoria since 1875, Tasmania since 1881, and Western Australia since 1896.

In oversea countries where this disease occurs it is responsible for serious losses. During the warm weather the mites are inactive and the animals may assume a normal, healthy appearance. Under these conditions the mites are found in such sheltered places as the base of the horns, the infra-orbital fossae, inside the ear, in the prepuce, and on the wrinkled scrotum of the wether. "Latent" scab, as this is called, is more prevalent in temperate climates, and becomes active again as soon as the cold weather commences.

Control. Recent work with BHC indicates that one dipping in a 0·1 per cent concentration containing 13 per cent gamma isomer will give complete control. Lime sulphur dips used at ten-day intervals, containing 1 per cent (England), or 1·5 per cent (South Africa and United States), polysulphide sulphur have proved very effective. Hand treatment of those parts of the body where the mites shelter is important, particularly if strategic dipping is carried out in the autumn.

Premises may remain infested for periods of fifteen to twenty days, though detached females do not lay eggs after the tenth day.

A 1·5 per cent polysulphide lime sulphur solution may be made by mixing 25 pounds of flowers of sulphur and 15 pounds of good quality slaked lime into a smooth paste with water, making up to 20 gallons with additional water and boiling and stirring until the mixture becomes a dark red-brown colour. It is then cooled and strained and made up to 100 gallons, when it is ready for use.

Psoroptic Mange in Cattle (*Psoroptes bovis* **(Gerlach)**). This disease is unknown in Australia, but in countries where it occurs it is the most serious and most common mange of cattle. It usually commences on the top of the neck and at the root of the tail.

Control. Measures recommended for the control of scab in sheep (p. 183) are also effective against this species. Brushes, rugs, etc., and infested premises should be disinfected.

Psoroptic Mange in the Horse (*Psoroptes equi* **(Hering)**). In the horse, the psoroptic mange mite usually infests those areas covered by long hair, such as the foretop of the head and the base of the mane and tail. The whole body may eventually become involved, with serious results. This disease has never been seen in Australia. A skin disease of horses in Queensland and New South Wales called Queensland itch, which is caused by the development of a hypersensitivity to the bites of sandflies (*Culicoides*), resembles psoroptic mange in many respects.

Control. The measures employed against scab in sheep will also control this species. Disinfection of harness, brushes, etc., and infested premises is necessary.

Psoroptic Otacariasis in the Horse (*Psoroptes hippotis* **Railliet and Henry**). This mite is confined to the external ear, and an infestation is denoted by the animal's shaking its head, rubbing its ears against a hard surface, and manifesting a touchiness of the poll. There is some suspicion that an intermittent oedema involving the base of the ear may also be associated with infestation.

P. hippotis differs from *P. equi* in that in the male only two of the three longer hairs on the posterior abdominal lobe are contiguous at their bases, whereas in *P. equi* all three hairs are contiguous (Fig. 119). *P. hippotis* is identical with *P. ovis* and *P. caniculi* in this respect. The latter species is seen in the ears of rabbits and is not uncommon in Australia in laboratory animals.

P. hippotis has so far been seen only in Queensland. It also occurs in France.

Control. P. hippotis could probably be controlled by thoroughly cleaning out the ear and swabbing with 0·1 per cent gamma BHC in liquid paraffin or any other good miticide as used against *Otodectes* in dogs (p. 187).

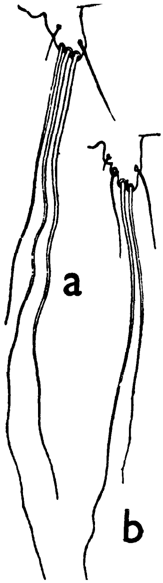

Fig. 119. Posterior abdominal lobe of (*a*) *Psoroptes equi*, male, and (*b*) *P. ovis*, male.
(*After Hirst.*)

Psoroptic Otacariasis in the Goat (*Psoroptes caprae* **(Railliet)**—Fig. 117). This condition sometimes spreads to the face. It has been seen in goats in Queensland.

Control. The control measures recommended against *P. hippotis* of the horse should be effective.

Chorioptic Mange

The mites belonging to the genus *Chorioptes* have an oval body, and tarsi with short, unsegmented pedicles. Large bell-shaped tarsal suckers are present on all legs of the male and on legs I, II, and IV of the female. The tip of the male abdomen is bilobed and is provided with spatulate setae; anal suckers are present and the last pair of legs are greatly reduced (Fig. 120). Copulatory tubercles are seen in the pubescent female. The males measure about 0·30 millimetre, and the ovigerous females about 0·40 millimetre in length.

The various forms that occur on their respective hosts are very similar morphologically, but exhibit a high degree of host specificity.

Life History. The life cycle stages consist of an egg, a six-legged larva, a nymph, a male, a pubescent female, and an ovigerous female. The larva has suckers on legs I and II and two hairs on legs III. The nymph is larger, the additional legs being furnished with a hair. The pubescent female is provided with suckers on legs I and II only. The life cycle may be completed in about ten days.

Importance. The mites live on the skin surface. The continual puncturing of the skin produces an inflammation with the formation of tiny vesicles. These exude serum that dries to form crusts. As the disease advances the mites move to the edges of the lesion and feed on the more healthy skin. In advanced cases the vesicles become confluent and, aided by mechanical injuries, scales and crusts form, and the skin becomes thickened and toughened, denuded of hair and thrown into folds. Chorioptic mange is not as serious as other kinds of mange, and frequently

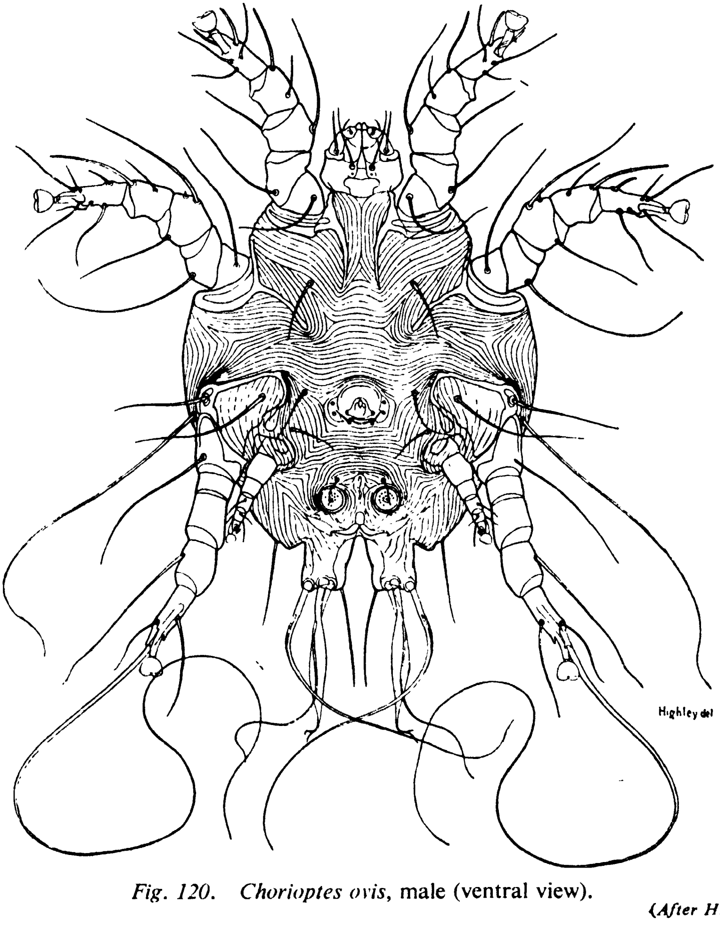

Fig. 120. Chorioptes ovis, male (ventral view).
(*After Hirst.*

the condition is mild and confined to the lower parts of the body—hence the alternative name, symbiotic mange.

Diagnosis. The mites are found in scrapings taken from the edges of the lesions.

Chorioptic Mange in the Horse (*Chorioptes equi* (**Gerlach**)). This condition, commonly known as leg mange, is usually confined to the legs below the knees and hocks, occasionally reaching the axilla and groin, and it is widespread throughout Australia as well as in other parts of the world. It produces an intense itching, causing the horse to stamp, paw, and kick. The animal is uneasy on its feet and frequently rubs the pastern with the opposite foot. Leg mange is considered in some quarters to be a prime factor of inefficiency and a shortened working life. Capped elbows, concussed limbs, fractures, and damage to the shoes are quoted as being among the effects of an infestation.

Control. The affected areas should be clipped and cleaned and washed with warm lime sulphur (1·0 to 1·5 per cent polysulphide sulphur), 0·1 per cent gamma BHC, or hand-dressed with sulphur and lard (one part of sulphur to four parts of lard). Treatment should be repeated at intervals of ten days until the condition is no longer apparent. The premises, etc., should be disinfected.

Chorioptic Mange in Cattle (*Chorioptes bovis* (**Gerlach**)). This condition usually starts at the root of the tail, which becomes covered with fine scales. Sometimes the fetlock region is involved. Irritation is usually slight, but if neglected the disease may spread to the croup, sacral region and back, perineum, inner thighs, udder, and scrotum, when it may be severe enough to affect the condition of the animal.

This disease is world-wide in its distribution, and in Australia is recorded from New South Wales and South Australia.

Control. Infected animals are scrubbed and sprayed with lime sulphur (1·5 per cent polysulphide sulphur) or 0·1 per cent gamma BHC.

Chorioptic Mange in Sheep (*Chorioptes ovis* (**Railliet**)). This disease is seen on the pasterns of sheep and the scrotum of rams. Affected animals rub the hindlegs, giving rise to a scaly condition of the cannons and pasterns. A considerable part of the scrotum may be involved, and the ram will kick at the scrotum to relieve the irritation.

In Australia this condition has so far been seen only in rams, and is recorded from New South Wales, Queensland and South Australia.

Control. Sometimes a prolonged search for the mites is necessary. Treatment is similar to that recommended for chorioptic mange in cattle.

Chorioptic Mange in Other Animals. Other species of chorioptic mites include *C. caprae* (Gervais) on the goat, and *C. caniculi* (Zürn) on the rabbit, neither of which is known in Australia.

Notoedric Mange

Notoedric mange or head mange is a very common disease of cats and occasionally is seen on dogs. The causal mite, *Notoedres cati* Hering (Fig. 121), is very similar in appearance to the sarcoptic mange-mite, but the anus is dorsal, whereas in *Sarcoptes* it is terminal.

Importance. Infestation is usually confined to the head and neck, commencing as a rule round the ears and eyes and on the forehead. Greyish crusts are formed, and in advanced cases the skin becomes hard, thickened, and creased. Itching varies in intensity according to the state of the disease.

Diagnosis. The mites may be found in suitably prepared scrapings.

Control. One of the oldest effective treatments is to bathe the affected areas with 1 per cent potassa sulphurata. Another effective sulphur treatment is sulphur in olive oil (one part of sulphur to eight parts of olive oil) applied after softening the scabs with green soap.

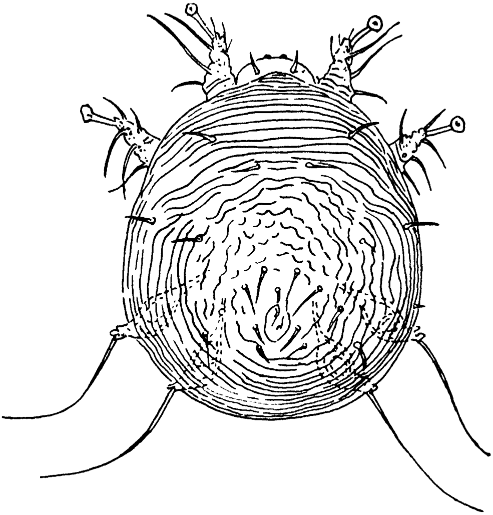

Fig. 121. The notoedric mange mite, *Notoedres cati*, female (dorsal view). (*After Helmsing.*)

The newer insecticides have received little attention. Bathing with 2 per cent Tetmosol, or dressing with 0·1 per cent gamma BHC in liquid paraffin, or with dibutyl- or dimethylphthalate, appears effective. Fatalities have occurred in cats, however, in which the affected areas were first washed with warm soapy water before applying the BHC. Chlordane, 0·25 per cent, has also been reported as effective. Several treatments may be required at intervals of three or four days.

Disinfection of the animals' sleeping quarters, brushes, etc., is necessary.

Otodectic Mange.

Otodectes cynotis (Hering) (Fig. 122) occurs in the external ear of dogs, and sometimes in the external ear of cats. These mites have rounded bodies and very short legs. Suckers on unsegmented pedicles are present on the tarsi of all legs of the male, and on legs I and II of the female. In the male legs III are longer than legs IV; in the female legs IV are very short.

Importance. The mites do not burrow into the skin, but their continual puncturing of it when feeding causes an intense irritation that the animal tries to relieve by shaking the head and scratching the ear. The ear becomes swollen, painful, and scabby, and is filled with wax and detritus. Nervous symptoms such as whining, howling, restlessness, and fits may be observed and, unless the condition is relieved, deafness may result. Sometimes the mites spread to the skin of the face and neck.

Diagnosis. The mites are readily found in material from affected ears.

Control. After the ear has been cleaned thoroughly it should be treated with a good miticide such as dibutyl- or dimethylphthalate, 0·1 per cent gamma BHC in liquid paraffin, 20 per cent benzyl benzoate emulsion (p. 179), carbon tetrachloride (one part) in castor or olive oil (four parts), or chloroform (one part) in olive oil (nine parts). Treatment is applied to all parts of the ear, paying particular attention to the cavum conchae, and to the surrounding area.

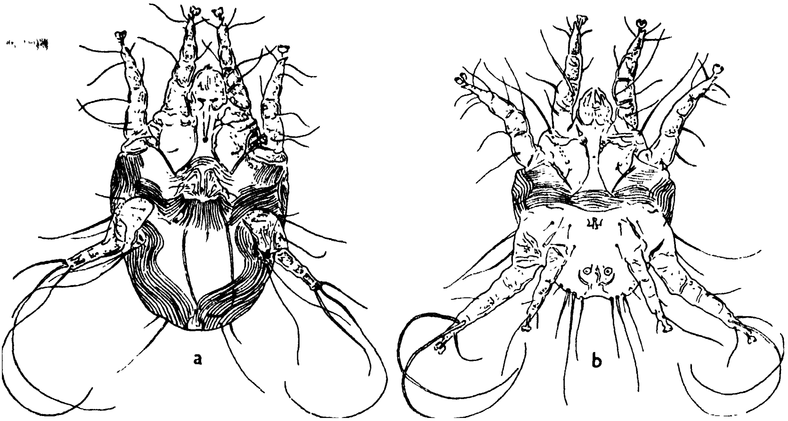

Fig. 122. The ear mite of the dog, *Otodectes cynotis.* (*a*) Female (ventral view); (*b*) male (ventral view). (*After Helmsing.*)

Several treatments at weekly intervals may be required to effect a cure.

Demodectic Mange

Demodectic or follicular mange is associated with tiny mites that occur in the sebaceous glands and hair follicles of man and many animals. The mites from different hosts are very similar in structure, differing from one another mainly in size. They are all very minute, being only 0·25 to 0·36 millimetre in length, and they possess an elongate, worm-like body, three-jointed, stumpy legs, and an annulated abdomen (Fig. 123).

Life History. The life history is imperfectly known. If mites are transferred from one host to another, nymphs of the new generation are seen in about ten days. That mites are commonly found in the lymphatic glands of the dog is interpreted by some authorities as representing a stage in the life cycle of the parasite, and by others merely as an indication that mites may be carried there from the skin to which they are subsequently unable to return. The mites have also been found in the blood, lungs, and faeces of the dog.

Importance. Infestation may be associated with a skin condition called demodectic mange, the etiology of which is obscure. Mites are frequently found in the skin of healthy animals. In man, for example, *Demodex folliculorum* Simon is very common but rarely becomes pathogenic.

D. canis is frequently seen in healthy dogs, but under certain obscure conditions the mite populations increase and become associated with an intensely irritating dermatitis, which may be further aggravated by invasion by pathogenic bacteria. These conditions may be connected with the resistance of the animal to infestation. In some quarters the predisposing cause is considered to be bacteria that invade the follicles.

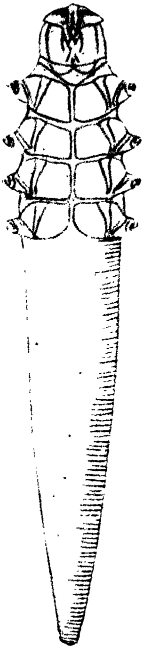

Fig. 123. The follicular mange-mite of the dog, *Demodex canis*, female (ventral view). (*After Hirst.*)

Diagnosis. Since mites can be found in the skin of healthy animals, it is evident that the presence of mites in skin scrapings is not, in itself, sufficient to justify a diagnosis. In most cases of demodectic mange large numbers of mites can be detected, and where only comparatively small numbers are seen the case has to be considered in conjunction with such factors as type and distribution of the lesions and the age of the animal where this is important. Examination of pustules reveals large numbers of mites, otherwise scrapings are made and examined as for sarcoptic mange.

Demodectic Mange or Red Mange in the Dog (*Demodex canis* **Leydig.**) This condition is most common in young animals under one year old, and in short-haired breeds. It usually commences as small, scaly, hairless spots around the eyes, at the sides of the muzzle, and on the hock and stifle joints. The patches become inflamed and are very itchy. As the affected areas spread, the lesions may be invaded by pus-forming bacteria, *Staphyloccus aureus* and *S. albus* particularly. This secondary infection may sometimes occur very early. Pustules occur in and under the skin and are accompanied by local destruction of the dermis. The pustules may become confluent, and the skin thickens and is easily damaged. There is also a squamous type, in which pustule formation is absent. This type is more localized in its distribution over the body and is accompanied by mild inflammation, loss of hair, dry skin, and some desquamation of the epithelium. As a rule the disease runs a slow course and may end fatally. It is accompanied by a characteristic mousy odour.

The nursing bitch appears to be the main source of transmission. Dogs frequently show a spontaneous recovery with age, and at twelve months may become free from this type of mange.

Control. The effectiveness of treatment is seriously handicapped by lack of knowledge of the etiology of the disease. Nothing is known of the predisposing causes, which may account for the success of some treatments with some dogs and failure with others. The list of treatments recommended by various authorities for this condition is a very lengthy one and includes, as well as the use of drugs, the application of ultraviolet rays, heat, and autogenous vaccines. A fairly high efficiency is recognized for benzyl benzoate and BHC, applied as for sarcoptic mange (p. 179). A wash of one part of rotenone, eighty parts of alcohol, ten parts of acetone, and ten parts of oleic acid is also said to be effective. Chlordane, 0·25 per cent, and Tetmosol, 2 per cent are also worth trying.

Whichever treatment is used, several applications will probably be required at intervals of three to four days. Care should be taken against injuring the skin, and attention given to improving the animal's general health. Treatment is most likely to be successful if commenced early.

Demodectic Mange in the Pig (*Demodex phylloides* **Csokor**). Infestation usually commences round the snout and eyes and spreads slowly over the throat, breast, abdomen, and other parts where the skin is soft and thin. The skin becomes inflamed and scurfy, the hair falls out, and small nodules are present. These may eventually break and discharge pus and, in bad cases, may become confluent and form suppurating cavities. This does not appear to be a very common disease of pigs in Australia.

Control. Badly affected pigs should be destroyed. Less severe cases may be treated with benzyl benzoate, BHC, or chlordane, as for *D. canis* in dogs.

Demodectic Mange in Other Animals. In the case of cattle, *D. bovis* Stiles forms small nodules in and under the skin, particularly of the neck, shoulders, breast, and dewlap. These nodules occasionally become pustular. In most instances the animal's health is not affected, but sometimes there is extensive itching and oedema of the pendulous parts, especially the dewlap. The presence of nodules in the skin greatly depreciates its value.

Demodectic mange in the horse, *D. equi* Railliet is usually of little importance, but sometimes the hair on the affected areas falls out, leaving peculiar bare spots, accompanied by itching and pustule formation. There are apparently two forms of the parasite, a large form found in the skin of the muzzle and eyelids, and a smaller form from the withers, neck, and other parts of the body.

D. ovis Railliet occurs in the sebaceous glands and hair follicles of the sheep. It is usually considered benign, but has been reported as causing severe irritation and wool damage. *D. caprae* Railliet infests the goat and *D. cati* Mégnin, the cat. Of these species, only *D. ovis* is reported from Australia.

Order PENTASTOMIDA

This order contains a number of blood-sucking endoparasites of vertebrates, in which the body of the adult is elongate, worm-like, and annulated. There are no appendages, no circulatory system and respiration is cutaneous. Two pairs of strong chitinous hooks are present on each side of the oral aperture, which is ventral in position, and the larva has only two pairs of legs. Tongue worms, as they are known, occur in the respiratory organs and body cavity of reptiles, birds, and mammals.

The Dog Tongue Worm (*Linguatula serrata* **Fröhlich**). This parasite is a cosmopolitan species, and, in the adult stage, infests the frontal sinuses and nasal cavity of the dog, fox, dingo, wolf, and other animals, including man. The male measures up to 2 centimetres and the female up to 13 centimetres. Both sexes have a flattened, serrated body, swollen anteriorly, with a median, longitudinal, dark line (Fig. 124 (*d*)).

Life History. The eggs when deposited contain fully developed embryos (Fig. 124(*a*)) and reach the exterior in the nasal discharges. For further development an intermediate host is required, for which purpose the sheep, goat, ox, rabbit, pig, cat, dog, and man are suitable. After hatching in the alimentary canal of the intermediate host, the larva (Fig. 124(*b*)) makes its way into the liver and mesenteric lymph glands. Here it moults

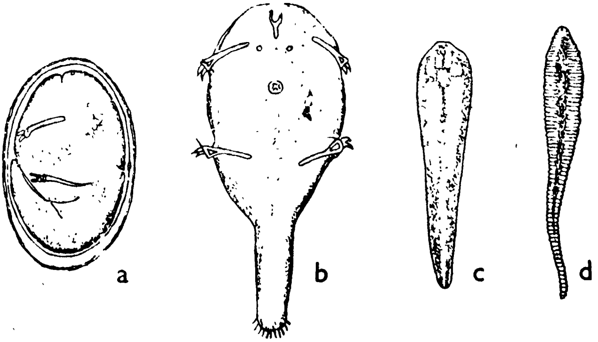

Fig. 124. The life cycle of the dog tongue worm, *Linguatula serrata*. (*a*) Ovum containing embryo; (*b*) larva; (*c*) nymph; (*d*) adult.

(*After Belding.*)

to the nymphal stage (Fig. 124(*c*)), which measures 5 to 6 millimetres and is whitish in colour and very similar in appearance to the adult. It usually lies in a small cyst surrounded by a thick, turbid fluid, and may remain alive as long as two and a half years. Animals become infested with the adult after eating material containing these nymphal forms, the nymphs attaching to the lining of the buccal cavity or pharynx, and later migrating to the nasal cavity. The adult stage is reached in less than four months and may persist as long as two years. The first eggs are passed six months after infection.

Importance. In localities where the parasite is very prevalent, for example, in Central Europe, it is a serious pest of dogs. It attaches high up in the nasal cavities and produces a severe irritation. Infested animals cough and sneeze, rub their noses, and frequently have a mucoid, blood-stained nasal discharge. It is present in Australia, the nymphal forms being frequently seen in cattle, where they are of little importance. Adults, though rare in dogs, are not uncommon in the fox, and have also been seen in the dingo. It seems likely that in Australia *L. serrata* is maintained mainly as a rabbit-fox parasite.

Control. Infested dogs are best treated by surgical means. Animals should be fed only well-cooked meat.

TICKS

Ticks can be distinguished from mites by their larger size, their tough leathery integument, the well-developed hypostome with its rows of strong, recurved teeth, and the presence of a pair of ventro-lateral chitinous plates through which the tracheae open.

MORPHOLOGY (Fig. 125)

The body of a tick is oval or elliptical in shape, covered with a tough, leathery integument, and without any visible demarcation between the cephalothorax and abdomen. At the anterior end is the capitulum or "head", which carries the mouth-parts and fits into a cavity of the body, the camerostome. The basal portion of the capitulum or basis capituli articulates with the body, and in female ticks has dorsally and on either side of its centre a pair of porose areas, which are circular or oval depressions containing a number of pits. The hypostome extends forward from the basis capituli and is a paired, club-shaped, spatulate or dart-like chitinous structure armed with rows of recurved teeth. This is the attaching organ of the tick, the recurved teeth being responsible for the head's remaining in the skin when the tick is forcibly removed. The teeth are arranged in rows, the number of which are of great taxonomic value, and are written, for example, as 4/4, which means four longitudinal rows of large teeth on each half of the hypostome. The paired mandibles or chelicerae are carried in finely denticulate sheaths and lie dorsal to the hypostome. Each mandible consists of a chitinous bar extending into the body of the tick and terminating in a digit composed of two movable articles. The internal article is continued forward into a long,

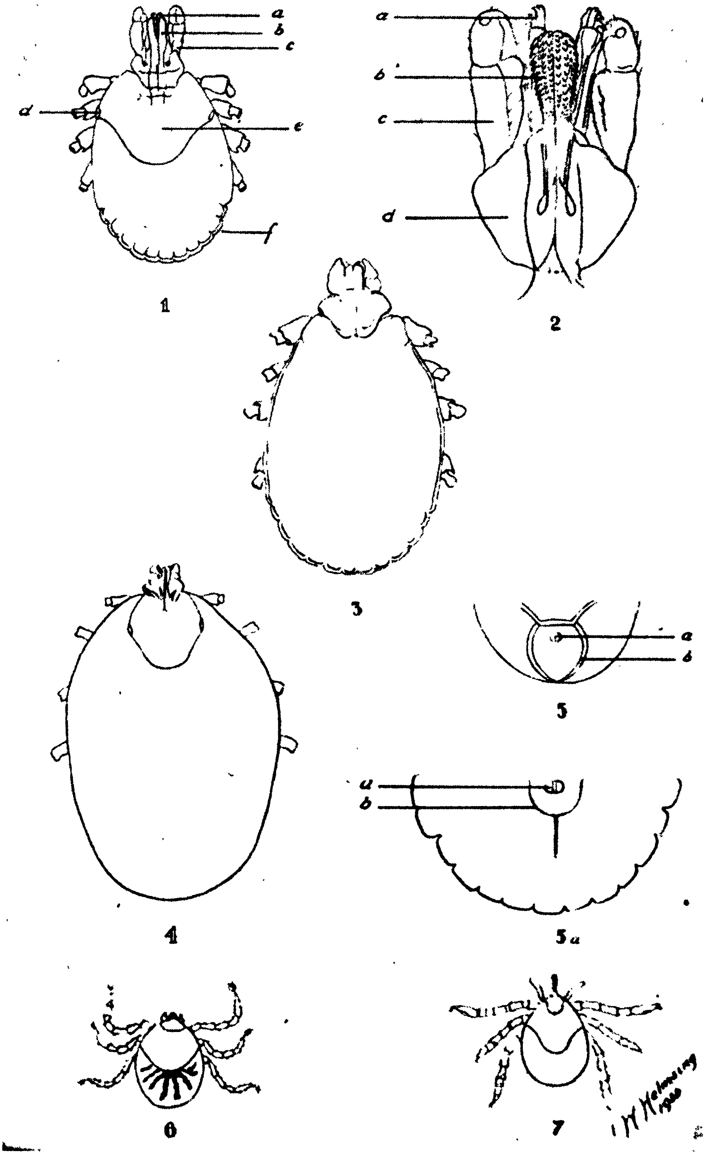

Fig. 125. External morphology of a tick. (1) Female (dorsal view), showing (*a*) chelicerae; (*b*) mandibular sheaths; (*c*) palps; (*d*) eyes; (*e*) scutum; (*f*) festoons. (2) Capitulum (ventral view), showing (*a*) chelicerae; (*b*) hypostome with its rows of teeth; (*c*) palps; (*d*) basis capituli. (3) Male (dorsal view), showing scutum covering most of the back (cf. scutum of female in (1)). (4) Engorged female showing small area of back covered by scutum. (5) Anal groove encircling the anus in front ((*a*) anus, (*b*) anal groove). (5a) Anal groove encircling the anus behind ((a) anus, (*b*) anal groove). (6) Larva of *Boophilus microplus*. (7) Larva of *Ixodes holocyclus*. (*After Helmsing.*)

hooked tooth and is provided with a dorsal process of one or more teeth. The external article has three or more teeth and articulates with the outer side of the internal article. On either side of the hypostome is a palp composed of four segments. When the tick is feeding, a rent is made in the skin by the articles of the chelicerae and the hypostome is then inserted.

The dorsal surface of the body in the so-called "hard" ticks, or Ixodid ticks, is provided with a dorsal shield or scutum, which covers almost the whole dorsal area in the male, but is greatly reduced in the female. This shield may be coloured or ornate, and sculptured and furrowed. Extending posteriorly from the inner angles of the scapulae, or shoulders of the scutum, are a pair of cervical grooves. Eyes, when present, are on the lateral margins of the scutum. About the centre of the scutum in the male, and just posterior to the scutum in the female, are a pair of spots or foveae. Lateral grooves extend along the sides of the scutum, which, in the male, may be prolonged posteriorly. Marginal grooves are seen along the sides of the body of the female, commencing at the postero-lateral scutal border. There are other grooves and depressions on the dorsal surface corresponding to lines of attachment of bands of muscles. The posterior margin of the body may be divided into a number of small folds, the marginal festoons.

The anal opening is situated ventrally and towards the posterior margin and is usually surrounded anteriorly or posteriorly by the anal groove. The males are sometimes provided with plates on each side of the anus, namely the adanal and accessory adanal plates. The genital opening is also ventral and is placed forward between the coxae of the legs. A genital groove extends posteriorly. The presence of a genital opening distinguishes between an adult and a nymphal tick. The paired spiracular or stigmal plates are ventro-lateral, either between the coxae of the third and fourth legs or behind the coxae of the fourth leg.

The legs are six-jointed and are fastened to the body by immobile coxae, which may be provided with prolongations or spurs. The coxa is followed by the trochanter, femur, tibia, and tarsi, which end in a short pedicle bearing a pair of claws, and a pulvillus. On the dorsal surface of the distal tarsus of the foreleg is a remarkable structure known as Haller's organ, which is composed of cup-shaped pores with sensory hairs and dermal cells and is probably olfactory in function. Coxal glands between coxae I and II secrete a tenacious fluid during feeding and copulation.

Fluids are sucked up through a channel formed between the mandibular sheaths and hypostome. This channel is bayed out towards its posterior end and here it receives the salivary duct. The salivary fluid is strongly haemolytic and very irritating. The food channel then leads into the pharynx, which is formed of chitinous plates and has a pumping function. The pharynx is continuous with the oesophagus, which leads through a mid- and hind-intestine into the rectum. The mid-intestine is provided both anteriorly and posteriorly with a number of blind diverticula with one or more secondary branches, and is capable of great distension. The hind-intestine is functionless in most ticks and excretion is carried out by the malpighian tubes. These end blindly anteriorly and are coiled to come into contact with almost every organ, particularly the intestinal canal and its diverticula, and finally enter the rectum. During periods of ovulation these tubes are seen through the dorsal surface as broad yellowish bands.

The ovary of the female is a large tubular organ lying across the body. Oviducts lead from each end of the ovary, and after a somewhat convoluted course unite to form the large sac-like uterus, which lies in the middle line below the mid-intestine. At its anterior end the uterus leads into the vagina, which opens through the genital aperture.

The male tick has a single testis. The vasa deferentia unite in the middle line to form a large lobulated organ, the "white gland" which appears to function as a seminal vesicle, and is surrounded by a number of accessory glands. Fertilization of the female is accomplished by the introduction into the female genital aperture of a spermatophore, a coiled ball of sperms enclosed in a delicate membrane. The spermatophore is ejected from the male genital opening into the corresponding aperture of the female after its dilation by the male's mouth-parts. There is no penis.

During oviposition the egg leaving the genital opening is rolled around until it comes into contact with the sticky secretion of Gene's organ. This organ is found only in the female and opens by a transverse slit in the fold of skin dorsal to the capitulum, or in some ticks by separate ducts in the camerostome. When contact with the secretion of this organ occurs, the egg is drawn towards the dorsal surface of the body.

Habits and Life History

Ticks are obligatory blood-sucking ectoparasites that attack all kinds of mammals, birds, reptiles, and amphibia. The species infesting cold-blooded animals are rarely seen on warm-blooded animals, and vice versa. Although there is usually little host specificity and the host range may be fairly wide, there are frequently certain hosts best suited to a species' development. Most ticks will attach to any part of the host's body, but usually show a preference for certain areas; others, such as the spinose ear-tick are restricted to the one habitat on the host.

Ticks may have to spend a considerable portion of their lifetime awaiting attachment to a suitable host, and the various life cycle stages are, therefore, very long-lived. In the absence of a host the larvae, nymphs, and adults may survive for many months, while the adults of some species may remain alive for several years.

There are four stages in the life cycle of a tick, namely, the egg, larva, nymph, and adult. The eggs are small spherical bodies that gradually darken as they approach hatching, and are deposited, singly or in masses, in the soil, vegetation, or other habitat of the ovipositing female. The larva or seed tick that hatches from the egg has only three pairs of legs (Fig. 125 (6), (7)). It attaches to a host as soon as its body has hardened and engorges with lymph or blood. When fully engorged it moults and becomes a nymph, with four pairs of legs. The nymph resembles the adult but is smaller and has no genital opening. This stage then feeds on a host and when fully fed prepares to enter the adult stage. In some species of ticks there are two nymphal stages. The moulting nymph gives rise to either a male or a female adult tick. On attaching to a host the adult female is, in the majority of species, capable of a considerable increase in size as she engorges, and when this is complete she drops off and lays her eggs. The male is smaller than the female and is an intermittent feeder, spending its life wandering in search of unfertilized females. Unlike the female it shows little increase in size.

This is the general plan of the tick life cycle. Certain differences in detail, however, provide four main types of life cycle, namely:

1. The larva attaches, engorges, and drops off the host to moult to the nymph. The nymph proceeds likewise and moults to the adult. The adult attaches, engorges, and, if a female, drops off to lay her eggs and then dies. This type of life cycle requires three hosts, which may or may not be the same species. Such a tick is a three-host tick.
2. The larva attaches, engorges, and moults to the nymph without dropping from the host. The nymph, however, after engorging, drops to the ground and moults to the adult. The adult then has to find a host on which to feed. Here two hosts, frequently of different species, are required, and the tick with this type of life cycle, is a two-host tick. The female lays only one batch of eggs and then dies.
3. In one-host ticks the complete life cycle from the time the larva attaches until the female drops off to lay her eggs is passed on the one host. After laying one batch of eggs the female dies.
4. The only stages that occur on the host for any length of time are the larvae, or in some cases, larvae and nymphs. The adults, and sometimes also the nymphs, hide away in sheltered places in the host's habitat and visit the host only to feed. The female is very long-lived and lays several batches of eggs during her lifetime.

IMPORTANCE

Ticks are notorious parasites of domestic animals and birds throughout the world and are responsible for serious economic loss. Heavy infestations cause a condition known as "tick worry", which is manifested by loss of condition and a severe degree of anaemia. This anaemia is due mainly, if not solely, to the blood removed by the parasites. Heavily infested animals become dull and listless and may die. Tick bites cause a scabby corrugated condition of the skin. Secondary infection may occur, followed by suppuration and sloughing. Hides are considerably reduced in value. Where screw-worm flies occur, tick bites are important sources of attraction.

In addition, ticks are vectors of many serious diseases, most prevalent in tropical and sub-tropical areas. In man, various typhus fevers, relapsing fevers, and tularaemia are tick-borne; whilst in livestock the most important include redwater, East Coast fever and anaplasmosis of cattle, Nairobi disease, biliary fever, louping ill and heartwater of sheep, biliary fever of horses and dogs, and spirochaetosis or tick fever of poultry.

There are also ticks that cause a frequently fatal condition of paralysis in man and animals.

CONTROL

The control of any species of tick involves, firstly, the destruction of the parasitic stages either by insecticides or, more rarely, by such measures as hand-picking or grooming; secondly, a thorough knowledge of the tick's life cycle and its host relationships; and thirdly, accurate information on the behaviour of those stages in the life cycle that occur away from the host. Where control is concerned chiefly with a tick-borne disease, a careful study of the epidemiology of the disease is essential.

Insecticides and Their Application. With intermittent feeders such as the poultry tick, the insecticide is applied as a spray, sometimes as a fumigant, against the ticks in their hiding places. Mineral oils, such as kerosene and fuel oil, coal tar derivatives—for example, creosote—and the chlorinated hydrocarbons are highly efficient for this purpose.

With ticks that spend considerable periods attached to the host, the insecticide is applied to the host. The selection of an insecticide in this case is restricted, for here its toxicity to the host must receive consideration. The oldest and most widely used insecticide for cattle, horses, and sheep is arsenic, which is employed as a watery solution of sodium arsenite. During recent years considerable attention has been given to the chlorinated hydrocarbons, DDT, BHC, chlordane, and toxaphene, and it is expected that because of their high toxicity to ticks, the protection afforded against reinfestation, and their relatively low degree of toxicity to the host, these compounds will displace arsenic from its role in tick control. Derris also finds a use as a tickicide, particularly on cats and dogs. The insecticide may be applied by dusting, hand-washing, spraying, or dipping.

Dusting. This method may be used in the case of small animals, such as dogs and cats.

Hand-washing or Hand-dressing. This is most frequently employed on dogs, though it may also be a method of application with small numbers of quiet cattle and horses. This type of treatment is essential with ticks that inhabit parts of the body—for example, the inside of the ears—that are difficult to wet with sprays or dips.

Spraying. The use of a spray by means of a bucket pump or knapsack spray is satisfactory for small numbers of quiet cattle and horses. During recent years efforts have been made to develop power-driven sprays for tick control. For this method, spray nozzles are fixed in convenient positions overhead and along the sides of a race through which the animals are driven whilst the sprays are in action. Draining pens at the exit end hold the cattle until all surplus fluid drains from them, and it is then returned to the unit through a system of filters.

In general, spraying is not regarded as highly efficient, owing to the difficulty of obtaining complete wetting, particularly in the region of the back of the head, top of the neck, escutcheon, and udder.

Dipping. This is the quickest and most effective method of treatment.

The animals are plunged into the insecticide in a large tank or vat (Fig. 126) until completely submerged, and then swim a short distance to the exit.

These vats or dips hold about 2000 to 3500 gallons, are of varying lengths, according to capacity, and are sufficiently narrow to prevent the animals from turning round. The dips, which are built of concrete, iron, wood, or sometimes puddled clay with sloping walls, are sunk into the ground. Draining pens at the exit end return to the dip the excess fluid removed by the animals. Dipped animals are held for ten to twelve minutes in the draining pens for maximum recovery of fluid. Each animal carries away a certain quantity of fluid on its body—in the case of bullocks an average of 0·8 gallon—and after a number of cattle have passed through the dip the quantity removed has to be replaced, a process referred to as "topping up the dip".

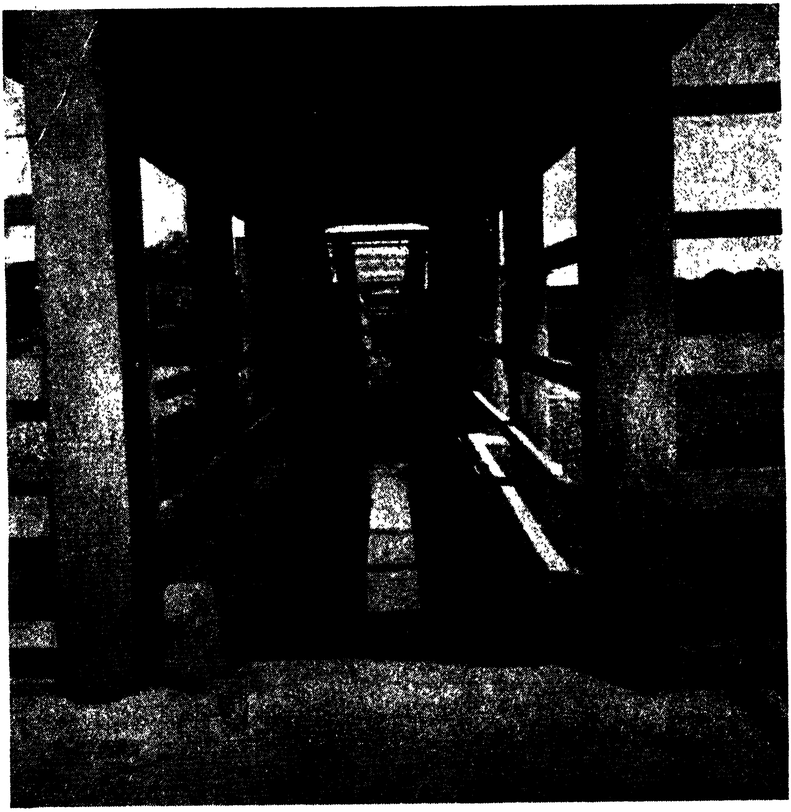

Fig. 126. A plunge dip for the treatment of cattle infested with ticks and lice. (*After Keith.*)

The Bearing on Tick Control of the Life Cycle and Host Relationships. The life history of a tick greatly influences the methods to be adopted for its control and eradication. The efficiency of insecticides, for example, is greatly increased if the intervals between treatments are such that the various stages are subjected to treatment before they become fully engorged and fall off into the pastures. The appropriate intervals vary from species to species and also according to whether the tick is a one-host, two-host or three-host tick. The species of the genus *Boophilus*, for example, are all one-host ticks, and the interval between treatments is such that the female tick is killed before she becomes fully engorged and drops off and lays eggs. In the case of *B. microplus* the minimum period taken by the female to reach this stage is nearly nineteen days, and of *B. annulatus* seventeen days. The dipping interval is therefore fixed for eradication purposes at fourteen days. With three-host ticks the dipping intervals are necessarily much shorter because the engorged larvae, nymphs, and females have each to be taken into consideration. Control and eradication of two-host and three-host ticks thus becomes extremely difficult, and is usually not very practicable, at least with arsenic. The position, however, should be improved by the use of the chlorinated hydrocarbons, because their residual toxicity permits treated animals to act as living poison baits for the pasture stages of the tick, and thus lengthens the dipping intervals.

Many ticks are known by common names such as the cattle tick, the dog tick, the horse tick, etc., which indicate that these ticks are most frequently seen on the particular animal from which the name is derived. As a rule, however, there are other hosts on which the parasites can spend all or part of their life cycle. In the case of the cattle tick full development can also occur on equines, deer, and sheep. The importance of these other hosts in the control of the tick must receive careful consideration. Control becomes very difficult in the case of two-host and three-host ticks when the larvae and nymphs occur also on wild mammals and birds. Sometimes an immature stage of an important tick is practically confined to wild life.

Control by Attacking the Larval Stages in the Pasture. This includes such measures as excluding all hosts from the pasture for a period, so as to kill the ticks by starvation, spraying the pastures with tick-destroying agents, using the host as a poison bait through the application of an insecticide with good residual toxicity, pasture improvement, and periodical burning of the pastures.

The larvae, nymphs, and young adults awaiting a host in the pasture are well adapted for this purpose, for they possess considerable powers of survival, extending in some cases up to two years. Undoubtedly, pastures would benefit considerably by being rested for such a period, but it is doubtful whether such a measure would be used except under special circumstances—as for example, during the eradication of *B. annulatus* in the United States, when pastures too rough to permit regular treatment of stock by dipping were cleansed by closing them for several months to cattle, horses, asses, and mules.

Preliminary observations in the United States show that DDT sprays and dusts applied to the pastures will give good control of such species as *Dermacentor variabilis* and *Amblyomma americanum.* Whether this measure will every be employed for large-scale routine control depends mainly on the development of an efficient method of application and on the expenditure involved.

Cattle treated with DDT remain toxic to larval *B. microplus* for periods of ten to fourteen days, and during this time thousands of larval ticks in the pasture are killed whilst attempting to attach. It might be expected, therefore, that the population of larvae in any pasture would be significantly reduced by heavy stocking with cattle dipped in this insecticide.

Pasture improvement has been found to give promising control of *Ixodes ricinus* in Great Britain. This tick requires a good deal of ground cover for protection from predators and especially from lethal conditions of low humidity. Pasture improvement, by the breaking up of the dense mat of vegetation, reduces ground cover and hence the tick population also. Whether or no pasture improvement would control other species of ticks can be determined only by a careful study of their ecology.

Theoretically, periodical burning of the pastures should destroy large numbers of ticks such as *B. microplus*, whose larvae gather in masses on the vegetation. Critical observations to confirm this have yet to be made.

Finally, it must be emphasized that very little is known of the behaviour of ticks during their non-parasitic life. Some progress has been made with a few species, such as *I. ricinus* in Great Britain and *D. variabilis* in the United States. Until this information is available, control rests mainly on efficient insecticides applied to kill the parasitic stages on the host.

Biological Control. No serious attempt has ever been made to control ticks by using parasites or predators. Their parasites are few, the best known being small encyrtid wasps, *Ixidophagus texanus* Howard and *Hunterella hookeri* Howard, which parasitize the immature stages, particularly nymphs. The former occurs only in the United States, whilst the latter is practically world-wide in its distribution. Ants appear to take great toll of the stages in the pastures and, in various countries, certain birds consume large numbers of ticks. In Australia the willie wagtail, *Rhipidura leucophrys* Latham, and the introduced common myna, *Acridotheres tristis* (Linn.), are well known for this habit.

CLASSIFICATION

There are two families, the Argasidae and the Ixodidae.

Family ARGASIDAE

Mouth-parts in adults and nymphs situated antero-ventrally and invisible when viewed from the dorsal surface, terminal or subterminal in the larvae; no porose areas; palpi ungrooved and leg-like; scutum absent; stigmal plates usually situated in front of the last pair of coxae; festoons absent; pulvilli vestigial or absent; eyes, when present, on the supracoxal folds; sexual dimorphism slight.

The adults are found in the habitat occupied by the host, which is attacked only when a meal of blood is desired. The larvae attach to the host till engorged, which may take several days. The nymphs of some species are similar in habit to the adult, and those of other species to the larva. The female lays several batches of eggs.

There are three genera, *Argas*, *Ornithodoros*, and *Otobius*. Some authorities consider *Ornithodoros* synonymous with *Argas*.

Genus Argas

Body with a distinct flattened margin, differing in structure from the rest of the body, and giving even engorged specimens a sharp-edged appearance; dorsum and venter provided with a number of symmetrically arranged discs, placed in more or less radial lines; eyes absent.

Only two species are important, namely, *A. persicus* (Oken), (p. 208) the common fowl tick, which is world-wide in its distribution (Fig. 128), and *A. reflexus* (Fabr.) the pigeon tick, which is common in parts of Europe and is also known in the United States, South America, and North Africa. It is a pest of pigeons and other birds. Both species are vectors of fowl tick fever (*Borrelia anserina*). *A. persicus* also carries *Aegyptianella pullorum* of poultry, and is capable of transmitting fowl plague (*Pasteurella avicida*).

Genus Ornithodoros

Body margin thick and not clearly defined, similar in structure to the rest of the integument and disappearing on distension; discs and mammillae arranged in a variety of patterns, but not radially; hypostome well developed in both sexes; eyes present or absent.

There are a number of species distributed throughout the world. Two are recorded from Australia, but only *O. gurneyi* Warburton (p. 210) is of interest (Fig. 129).

Many species of this genus are vectors of human relapsing fevers in Africa, the Mediterranean region, and the warmer parts of the United States, Central and South America. A large number of strains and species of spirochaetes are involved, the best known being *Borrelia duttoni*, the cause of Central African relapsing fever, of which *O. moubata* Murray is the vector. The organisms are transmitted in a fluid that flows copiously from the coxal glands at the base of the legs and enters the wound made by the mouth-parts. This tick is also a vector of *B. anserina* of poultry, and with *O. hermsi* and *O. turicata* of Q fever (*Coxiella burnetii*).

The bites of several species of *Ornithodoros* are recorded as causing severe reactions in man.

Genus Otobius

Like *Ornithodoros*, but hypostome, although well developed in nymphs, vestigial in adults; integument of adult granulated, striated, and with spines in the nymph; capitulum distant from the anterior end in the adult, near the margin in the nymph; eyes absent.

Here is included *O. megnini* (Dugès) (syn. *Ornithodoros megnini*) the spinose ear tick, which in the larval and nymphal stages occurs in the ears of mammals. Horses, cattle, and dogs suffer severely. The adults are not parasitic and are not seen on animals. It is recorded from South Africa, the United States, Mexico, the Argentine, and India.

Family IXODIDAE

Mouth-parts terminal, and visible from the dorsal surface; palpi grooved; a scutum present and covering almost the entire dorsal surface of the male, but only a comparatively small area in the larva, nymph, and female; porose areas present in the female, which is capable of considerable distension during engorgement; stigmal plates posterior to coxae IV; festoons usually and pulvilli always present; eyes present or absent.

The species of this family are one-host, two-host, or three-host ticks. The female lays one batch of eggs and then dies.

The most important genera are *Ixodes*, *Boophilus*, *Margaropus*, *Haemaphysalis*, *Rhipicephalus*, *Dermacentor*, *Otocentor*, *Amblyomma*, *Hyalomma*, and *Aponomma*. Of these *Margaropus*, *Dermacentor*, *Otocentor*, and *Hyalomma* are not represented in Australia.

Genus Ixodes

Inornate; without eyes or festoons; anal groove surrounding the anus in front; male scutum surrounded by a marginal body-fold; sexual dimorphism frequently very pronounced, especially in regard to the capitulum.

Three species of this genus are recorded from livestock in Australia, namely, *I. tasmani* Neum. from cattle and horses in Queensland, *I. australienis* Neum. from dogs in Western Australia, and *I. holocyclus* Neum., the scrub or paralysis tick, from all kinds of livestock in eastern Australia (Fig. 130) (p. 211). Important species in other parts of the world include *I. ricinus* (Linn.), which in Great Britain is a serious pest among sheep, to which it also transmits louping ill and tick-borne fever. Here and elsewhere in Europe this tick is a vector of tick fever (*Babesia bovis*) in cattle, while *I. persulcatus* is a vector in Russia. Three species are associated with a condition of paralysis in sheep, namely, *I. ricinus* in Crete and *I. pilosus* Koch and *I. rubicundus* Neum. in South Africa. The South African species may also cause paralysis in goats and, more rarely, cattle. *I. scapularis* Say transmits anaplasmosis (*Anaplasma marginale*) of cattle in North America.

Genus Haemaphysalis

Inornate; palps and hypostome short; article II of palps frequently extending laterally beyond the basis capituli; eyes absent; festoons present; anal groove encircling the anus behind; male without ventral plates or shields.

The Australian species of interest include *H. bispinosa* Neum. (Fig. 132) an introduced species that attacks domestic animals and birds, and in India transmits *Babesia gibsoni* of dogs (p. 215); *H. bancrofti* Warburton and Nuttall, a native species not uncommon on cattle (p. 217); and *H.*

humerosa Warburton and Nuttall, a vector of human Q fever (*Coxiella burnetii*) and important in maintaining the disease among bandicoots, a marsupial reservoir host. This tick rarely attacks cattle and horses.

This genus includes a number of species in other parts of the world that transmit various diseases, such as *H. leachi* (Audouin), the dog tick of West, Central, East, and South Africa, and a vector of canine piroplasmosis (*Babesia canis*) and of human tick bite fever (*Rickettsia rickettsi* var. *conori*); *H. cinnabarina* var. *punctata* Canes, a vector of tick fever (*Babesia bigemina*) and anaplasmosis (*Anaplasma marginale*) of cattle in Europe, and also recorded as causing paralysis among sheep in Macedonia; and the North American species *H. leporis palustris* Packard, an important vector of the organisms of human tick typhus or Rocky Mountain spotted fever (*R. rickettsi*) and of tularaemia (*Pasteurella tularensis*) among rabbits, which are reservoir hosts of these diseases.

Genus Rhipicephalus

Usually inornate; palps and hypostome short; eyes and festoons present; basis capituli hexagonal; anal groove encircling the anus behind; coxae I deeply bifid; male with a pair of adanal and usually also a pair of accessory adanal shields.

This genus is outstanding in the number of species that are vectors of serious diseases among domestic animals and man. These are tabulated on p. 204.

In some cases the tick vectors have been shown experimentally to be capable of transmitting the disease, but are not important natural vectors. *R. sanguineus*, for example, is an experimental vector of Rocky Mountain spotted fever and Q fever in man and also of anaplasmosis in cattle, but plays little part in the epidemiology of these diseases.

With the exception of *R. evertsi* and *R. bursa*, which are two-host ticks, the species mentioned above are three-host ticks. *R. sanguineus* is the only representative of the genus in Australia (Fig. 133) (p. 217).

Genus Boophilus

Inornate; palps and hypostome short, palps with prominent transverse ridges; eyes present; festoons absent; anal groove obsolete in the female, at most only faintly visible in the male; male very small with adanal and accessory anal shields.

The species of this genus are all one-host ticks. At the beginning of this century *B. annulatus* (Say) was widely distributed throughout the southern United States, from which it has since been almost completely eradicated, now being seen only in Florida and in the vicinity of the Mexican border. It is also present in Mexico. *B. microplus* (Canes.) occurs in South America, Mexico, Florida in the United States, India, Malaya, the Philippine Islands, the East Indies, Noumea and Australia (Fig. 135) (p. 221) *B. decoloratus* Koch and *B. fallax* Minning are African species. *B. calcaratus* is found in southern Europe and in North Africa. All are important parasites of cattle and, to a lesser extent, of horses. They are capable of causing serious losses *per se* and, furthermore, are vectors of

SPECIES OF RHIPICEPHALUS AND DISEASES TRANSMITTED

Disease	*Causal Organism*	*Host*	*Tick Vector*	*Distribution*
East Coast fever	*Theileria parva*	Cattle	*R. appendiculatus*	Africa
			R. capensis	Africa
			R. evertsi	Africa
			R. neavei	Africa
			R. simus	Africa
Theileriasis	*T. mutans*	Cattle	*R. appendiculatus*	Africa
			R. evertsi	Africa
	T. ovis *T. hirci*	Sheep and goat	*R. bursa*	Europe
Tick fever	*Babesia bigemina*	Cattle	*R. evertsi*	Africa
			R. appendiculatus	Africa
			R. bursa	Africa
	B. bovis	Cattle	*R. bursa*	Europe
	B. berberam	Sheep	*R. bursa*	Africa
Biliary fever	*Nuttallia equi*	Horse	*R. evertsi*	Africa
			R. bursa	Europe
	B. trautmanni	Pig	*R. sanguineus*	Europe
	B. canis	Dog	*R. sanguineus*	India, U.S.A., and elsewhere
	B. gibsoni	Dog	*R. sanguineus*	India
	B. ovis	Sheep	*R. bursa*	Europe
	B. motasi	Sheep	*R. bursa*	Europe
	Hepatozoon canis	Dog	*R. appendiculatus*	Africa
			R. sanguineus	Africa
Anaplasmosis	*Anaplasma marginale*	Cattle	*R. bursa*	Europe and Africa
			R. simus	Africa
			R. sanguineus	U.S.A.
Spirochaetosis	*Borrelia theileri*	Cattle	*R. evertsi*	Africa
Relapsing fever	*B. hispanica*	Man	*R. sanguineus*	Spain, Morocco
Nairobi Sheep disease	Virus	Sheep	*R. appendiculatus*	Africa
Louping ill	Virus	Sheep	*R. appendiculatus*	Africa
Equine encephalitis	Virus	Horse Man	*R. sanguineus*	U.S.A.
Rickettsiosis	*Rickettsia canis*	Dog	*R. sanguineus*	Africa
	R. ovina	Sheep	*R. bursa*	Africa
Rocky Mountain spotted fever	*rickettsi*	Man	*R. sanguineus*	U.S.A.
Tick-bite fever	*R. rickettsi* var. *conori*	Man	*R. appendiculatus*	Africa
Fièvre Bouttonneuse	*R. rickettsi* var. *conori*	Man	*R. sanguineus*	Mediterranean
Q fever	*Coxiella burnetii*	Man	*R. sanguineus*	Australia
Sao Paulo fever	*R. rickettsi*	Man	*R. sanguineus*	Brazil
Tularaemia	*Pasteurella tularensis*	Man	*R. sanguineus*	U.S.A.

highly pathogenic organisms. Those affecting cattle include redwater (*Babesia bigemina*) transmitted by all the above species, babesiellosis (*B. argentina*) of which *Boophilus microplus* is a vector, anaplasmosis (*Anaplasma marginale*) carried by *B. annulatus*, *B. microplus*, and *B. decoloratus*, spirochaetosis (*Spirochaeta theileri*) transmitted by *B. decoloratus*, *B. annulatus*, and *B. microplus* and theileriasis or pseudo East Coast fever (*Theileria mutans*) transmitted by *B. decoloratus* and *B. microplus*, and *T. annulata* carried by *B. calcaratus*. The latter species also carries *Babesia caballi* of the horse in Italy. Two species are also concerned with diseases affecting man, namely, *B. decoloratus*, which is a vector of tick-bite fever (*R. rickettsi* var. *conori*), and *B. microplus* of Australian Q fever (*Coxiella burnetii*), of which cattle are reservoir hosts.

Genus Margaropus

Very similar to *Boophilus*; the male, however, with the fourth pair of legs much enlarged and with a median ventral plate prolonged into two spines on either side of the anus.

There is only one species, *M. winthemi* Karsh, the so-called winter tick of horses in South Africa and South America.

Genus Dermacentor

Ornate; palps and hypostome short, the palps broad, with a postero-dorsal elevation; hypostome with four rows of teeth; eyes and festoons present; basis capituli quadrangular dorsally; coxae I bifid; anal groove encircling anus behind; male without ventral plates or shields.

This genus reaches its highest development in North America, where several species are vectors of serious diseases, the most important disease being tick typhus or Rocky Mountain spotted fever of man (*R. rickettsi.*) In the Rocky Mountains and Cascade Mountains area, *D. andersoni* Stiles is the principal vector, whilst in the Atlantic Coast areas this role is filled by *D. variabilis* (Say). These ticks also transmit tularaemia (*Pasteurella tularensis*) to man and animals, anaplasmosis (*Anaplasma marginale*) to cattle, and cause severe losses, in the case of *D. andersoni*, among cattle, sheep, dogs, and other animals, through tick paralysis. *D. andersoni* is, furthermore, a vector of equine encephalomyelitis. *D. occidentalis* Marx carries tick typhus, tularaemia, and anaplasmosis of cattle. *D. albipictis* Pack., a one-host species, is a serious pest of cattle and horses and is seen on its hosts only during the winter, and can transmit anaplasmosis. *D. reticulatus* (Fabr.) is a European species that transmits *Babesia canis* of dogs and *B. caballi* of horses. In south-east Russia *D. silvarum* Olen. is a vector of *B. caballi* and *Nuttallia equi* of horses and of *Theileria ovis* and *Anaplasma ovis* of sheep, and in Siberia, of tick typhus of man. *D. nuttalli* Olen. is also a typhus vector in that country.

This genus is not represented in Australia.

Genus Otocentor

Similar to *Dermacentor*, but inornate and the hypostome has only three rows of teeth.

This genus contains a single species, *O. nitens* (Neum.), which is a serious pest of horses in Central America and the southern United States.

Genus Amblyomma

Usually ornate; palps and hypostome long; eyes and festoons present; anal groove encircling anus behind; male without adanal shields, but small ventral plaques may be present close to festoons.

The Australian species are parasitic mainly on reptiles and these rarely attack domestic animals. One species, *A. triguttatum* Koch, a common tick on kangaroos, is frequently seen on cattle, sheep, horses, and dogs, but never in any numbers (p. 220).

Species of this genus are of the highest importance among livestock in other parts of the world. *A. hebraeum* Koch, found in the warmer parts of Central and South Africa, transmits heartwater (*Rickettsia ruminantium*) of sheep, cattle, and goats and tick-bite fever of man (*R. rickettsi* var. *conori*). In Kenya heartwater is carried by *A. variegatum* (Fabr.) which is also a vector of Nairobi sheep disease. The important American species include *A. americanum* (Linn.) a vector to man of Rocky Mountain spotted fever (*R. rickettsi*), tularaemia (*Pasteurella tularensis*), and Q fever (*Coxiella burnetii*), *A. maculatum* Koch, a serious pest of cattle and horses in the Gulf Coast areas of the United States, whose bite is very attractive to the screw-worm fly, *Callitroga hominivorax*; and *A. cayennense* (Fabr.), which transmits the Brazilian strain of Rocky Mountain spotted fever (*R. rickettsi*) to man. This species is also a serious pest of cattle in that its bites are a source of attraction to the tropical warble fly, *Dermatobia hominis*.

Genus Aponomma

Similar to *Amblyomma*, but eyes vestigial or absent and the body frequently very broad and almost circular in outline (Fig. 127).

The species of this genus occur almost exclusively on reptiles and are rarely seen on domestic animals. In Australia one occasionally sees *A. hydrosauri* Denny, *A. trachysauri* (Lucas), *A. simplex* Robinson and *A. trimaculatum* (Lucas) on cattle and horses.

Genus Hyalomma

Rarely ornate; palps and hypostome long; eyes present; festoons present or absent; male with adanal and accessory adanal shields and frequently a pair of chitinous processes posteriorly.

The identification of the species of this genus is difficult, for the nomenclature is very confused. A wide range of variations occurs within each species and it is apparent that this confusion can be eliminated only by a careful study of the progeny of the females.

This genus is practically confined to Africa, the Mediterranean Basin, Asia Minor, Russia, and India. Many species are serious pests of livestock, because of their severe bite and the secondary infections that frequently result therefrom.

The bont-leg ticks, *H. rufipes rufipes* C. L. Koch and *H. transiens*

Delpy, are important parasites of cattle and other animals in southern Africa. The former species is a vector of East Coast fever of cattle (*Theileria parva*) and also of *T. annulata*. *H. excavatum* C. L. Koch and *H. dromadarii* C. L. Koch are serious parasites of stock in Palestine and India respectively. *H. dromadarii* also carries *T. annulata*, and certain other species of the genus *Hyalomma* are vectors of this organism in northern Africa and Russia. *Nuttallia equi* and *Babesia caballi* of the horse and *Anaplasma marginale* of cattle are also carried by species of *Hyalomma*.

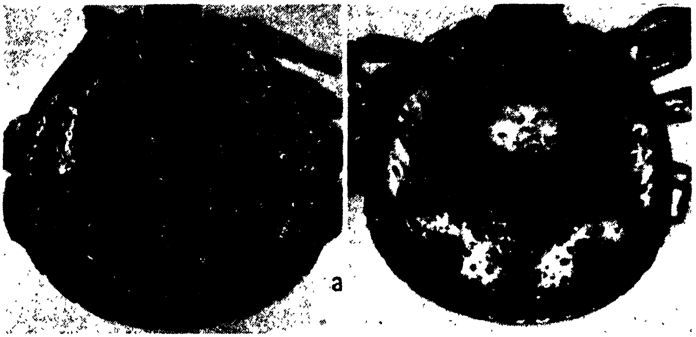

Fig. 127. (*a*) Scutum of male *Aponomma trachysauri*; (*b*) Scutum of male *Aponomma trimaculatum*. (*After Keith.*)

IMPORTANT SPECIES OF TICKS

The ticks commonly associated with domestic animals and birds in Australia are differentiated in the following key:

KEY TO THE ADULT TICKS COMMONLY ASSOCIATED WITH LIVESTOCK IN AUSTRALIA

1. Mouth-parts ventral; no dorsal shield or scutum............................ 2
   Mouth-parts terminal; dorsal shield or scutum present.......................... 3
2. Body with a distinct flattened margin, differing in structure from the rest of the body; the poultry tick....................... *Argas persicus* (p. 208)
   Body margin thick, not clearly defined, similar in structure to the rest of the body and disappearing on engorgement; the kangaroo tick................. .... *Ornithodoros gurneyi* (p. 210)
3. Anal groove encircling the anus in front, meeting behind at the body margin in the female, narrowly open in the male; the scrub or dog tick... .... *Ixodes holocyclus* (p. 211)
   Anal groove encircling the anus behind or obsolete............................ 4
4. Anal groove obsolete, festoons absent, legs pale; the cattle tick.............. .... *Boophilus microplus* (p. 221)
   Anal groove distinct and encircling the anus behind; festoons present; legs dark.. 5
5. Palps and hypostome long; eyes present; scutum of female with an ornate spot in its posterior angle and sometimes also in the lateral angles; the ornate kangaroo tick.......................... *Amblyomma triguttatum* (p. 220)
   Palps and hypostome short; scutum not ornate.............................. 6

6. Eyes present; article *2* of palps not projecting laterally beyond the basis capituli; coxae I deeply bifid; the brown dog tick.. *Rhipicephalus sanguineus* (p. 217)
   Eyes absent; article *2* of palps projecting laterally beyond the basis capituli; coxae not bifid.. 7
7. Article *2* of palps strongly salient laterally; article 3 devoid of a distinct dorsal spine on its posterior border, which may, however, protrude slightly; the wallaby tick................. *Haemaphysalis bancrofti* (p. 217)
   Article *2* of palps only slightly salient laterally; posterior border of article 3 with a distinct dorsal spine; the New Zealand cattle or bush tick .... *Haemaphysalis bispinosa* (p. 215)

The Poultry Tick (*Argas persicus* (**Oken**)). Adult ticks are slaty-blue in colour, with an oval body, the margin of which is composed of quadrangular units or cells, each enclosing a circular pit. The male is smaller than the female and narrower anteriorly. The female genital opening is slit-like and broader than the capitulum; that of the male is half-moon shaped and surrounded by an oval ring (Fig. 128).

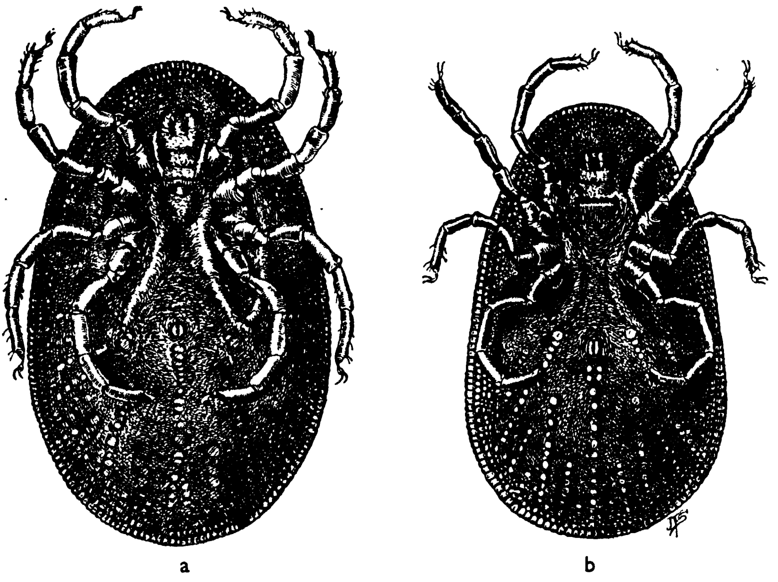

Fig. 128. The poultry tick, *Argas persicus*. (*a*) Male (dorsal view); (*b*) female (dorsal view).

(*After Helmsing.*)

This is a cosmopolitan species, which has been recorded from all States in Australia except Tasmania. It is widespread throughout Queensland and the Northern Territory. In New South Wales it occurs mainly west of the Divide, and in Victoria in the drier areas and round Melbourne. In South Australia it is present mainly in the drier parts of the State, and in Western Australia it is common in the vicinity of Perth and widespread throughout the Kimberleys.

Habits and Life History. Both nymphs and adults are nocturnal in habit, hiding away in cracks and crevices during the day. The adults are fully fed in one to one and a half hours. The spherical, brownish eggs are deposited by the female ticks in their daytime hiding places in the poultry-house, under the bark of nearby trees, and in any litter close to the poultry-house. The eggs are deposited in batches of 100 to 250, each female being capable of laying four to seven batches of eggs during her lifetime. Hatching occurs in ten to twenty-one days in warm weather, and the larvae, after hardening, attach themselves to the birds, most frequently on the breast, under the wing, and on the thighs. They remain on the bird until fully engorged, a matter of four to ten days. On leaving the host, the larvae then seek a suitable hiding place and, after about four to ten days, moult to the first-stage nymph. There are two nymphal stages, each of approximately fourteen days, each stage taking three to four blood meals. The second-stage nymph finally moults to form the adult tick, which feeds and, if female, lays her first batch of eggs five to seven days later.

Importance. All classes of poultry are attacked; and when sufficiently numerous the birds are seriously irritated, become restless, and may lose a considerable quantity of blood. Egg production is affected and may cease. Mortalities may occur, especially among young birds. Caged birds, such as canaries, are particularly susceptible to attack.

The poultry tick is the principal vector of *Borrelia anserina*, the organism of fowl tick fever and a cause of serious mortalities. This disease is widespread, occurring wherever ticks are present. The ticks may remain infective for six months or more. Birds become infected usually after being bitten by the tick, but infection can also occur when ticks are eaten or when infected tick faeces is rubbed into an abrasion. All stages of the tick may transmit the disease, the spirochaete being passed through the tick egg. The poultry pyroplasm, *Aegyptianella pullorum*, which occurs in Africa and other countries, is also transmitted by this tick. This disease is carried by adult ticks that have previously fed on infected birds. Such ticks may retain their infection for at least 162 days. Fowl-pox is another disease that can be carried, at least experimentally, by this tick.

Control. The habit of *Argas persicus* of sheltering in cracks and crevices makes it a rather difficult pest to control. Adults have phenomenal powers of survival in the absence of suitable hosts—for periods up to six years; and vacating infested premises for a time is therefore of little use. A badly infested poultry-house is best burnt and the birds quarantined for about twelve days before occupying their new quarters. Otherwise the following measures should be enforced:

1. Clean up and burn all litter, nesting straw, etc.
2. Spray thoroughly with crude or fuel oil, creosote, kerosene, 5 per cent DDT, 0·1 per cent gamma BHC, or 0·25 per cent chlordane. The spray should be applied under good pressure and forced into all cracks and crevices. Any loose timber and the perches should first be removed and given special attention. The possibility of egg and carcass taint from BHC and DDT should be borne in mind. Several treatments at intervals of 21 to 28 days, particularly with kerosene, crude oil, or creosote, may be necessary for eradication.

3. Birds may be protected from attack by suspending the perches on wires from the roof, or building them on supports arising from the floor, care being taken that the perches do not touch the walls. To prevent the ticks from crawling down the wires or up the supports, these are passed through cups filled with oil.

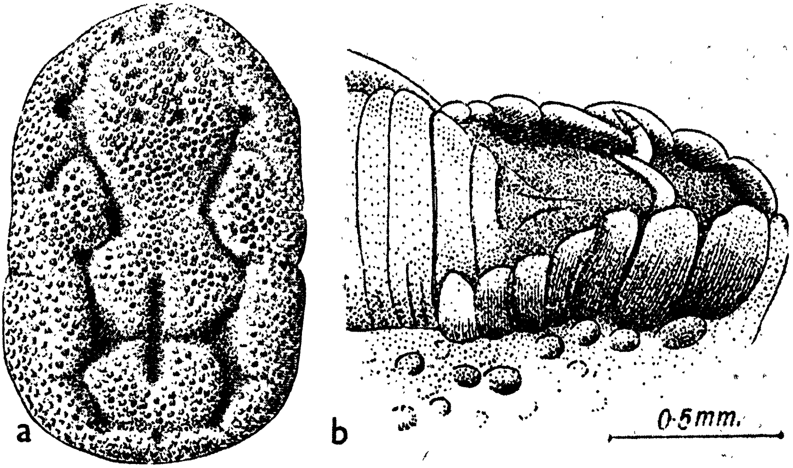

Fig. 129. Ornithodoros gurneyi. (*a*) Adult (dorsal view); (*b*) hood, highly magnified.

(*After Warburton.*)

4. Since larval ticks may be present on birds introduced into the flock, such birds should be quarantined for twelve days. The coops holding these birds should be either burnt or thoroughly cleaned and sprayed.

The Kangaroo Tick (*Ornithodoros gurneyi* **Warburton**). The adult ticks are an earthy-brown in colour, and have a mamillated integument furnished with dorsal depressions and discs. There are no eyes, and the species is characterized by a small capitulum, which is retractile within a "hood". The hood has a separate anterior piece followed by a free side-piece, and is completed by a movable cheek which is marked by furrows into distinct portions (Fig. 129). There is a ring of closely set hairs around the base of each trochanter.

This species is confined to Australia and is recorded from northern Western Australia, Central Australia, the Northern Territory, Queensland, and north-west New South Wales. In Queensland the ticks are widely distributed throughout the inland areas, the most easterly locality from which ticks have been recorded being Charters Towers, approximately eighty miles from the coast.

Habits and Life History. The adults and nymphs are found in the soil and debris of places frequented by kangaroos and wallabies, such as under bushes and trees and in caves. Nothing is known of the habits of the larvae, but in all probability these remain attached to their marsupial hosts until fully engorged. The adults and nymphs, when a suitable host presents itself, emerge from the soil and having fed, drop off and bury themselves again. According to some observers adult ticks engorge in five to ten minutes; others say thirty to forty minutes.

Importance. The ticks have been known to feed on man and on the horse and dog, and will probably attack other domestic animals. Mice are also suitable hosts. In man, the bite may be followed by severe but temporary reactions. A swelling as big as a hen's egg may appear, and headache, interference with vision—even temporary blindness—vomiting, and collapse have been recorded. No ill-effects have been reported from the horse and dog. The kangaroo tick can successfully transmit Q fever (*Coxiella burnetii*) under experimental conditions.

The Scrub Tick or Dog Tick (*Ixodes holocyclus* **Neumann**). The male is a flat, oval, yellowish tick. The unfed female is also yellowish in colour but, as it engorges, the colour becomes greyish with a brown line encircling the body. A fully engorged female tick may measure 15 to 18 millimetres. The palps are very long, much longer than the hypostome. The anal groove in the female is at first parallel, then converges to meet at the posterior border (Fig. 130 (*b*)). In the male the groove remains narrowly open (Fig. 130 (*a*)). *I. holocyclus* occurs in eastern Australia,* New Guinea, and portions of India and the East Indies. In Australia it is recorded from Queensland, New South Wales, Victoria, and Tasmania. In Queensland it is chiefly coastal and is frequently associated with rain-forest country, being most prevalent in areas such as the Atherton Tableland, McPherson Range, and Bunya Mountains. In New South Wales, except in the North Coast district, where it is found as far inland as the Richmond River watershed, it rarely occurs more than ten miles from the coast, and is particularly common in the neighbourhood of Sydney. It is seen on the east coast of Victoria as far south as Lakes Entrance. In Tasmania it has been found on the east coast and in the vicinity of Hobart.

Habits and Life History. This tick is a native species and its hosts include various species of marsupials, such as the bandicoot, wallaby, kangaroo, native bear, and pouched mouse. Bandicoots, *Isoodon tosorus* and *Perameles nasuta*, appear to be favoured hosts. It will also attack man, cattle, sheep, horses, dog, cat, pig, rabbit, rat, and the domestic fowl. The scrub tick is a three-host tick, the various life cycle periods being as follows:

Period	*Days*
Pre-oviposition ...	11 to 20
Incubation ...	49 to 61
Larval engorgement	4 to 6
Larval moult ...	19 to 41
Nymphal engorgement	4 to 7
Nymphal moult ...	21 to 71
Female engorgement	6 to 21

The average number of eggs laid by each female is 2500. After hatching or moulting the respective stages take about seven days to harden before seeking a host.

Unfed larvae (Fig. 125(7)) will survive in the laboratory for as long as 162 days, unfed nymphs for 275 days, and females for 77 days. The

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* Nuttall, Warburton, Cooper and Robinson (1911) record this species also from Western Australia.

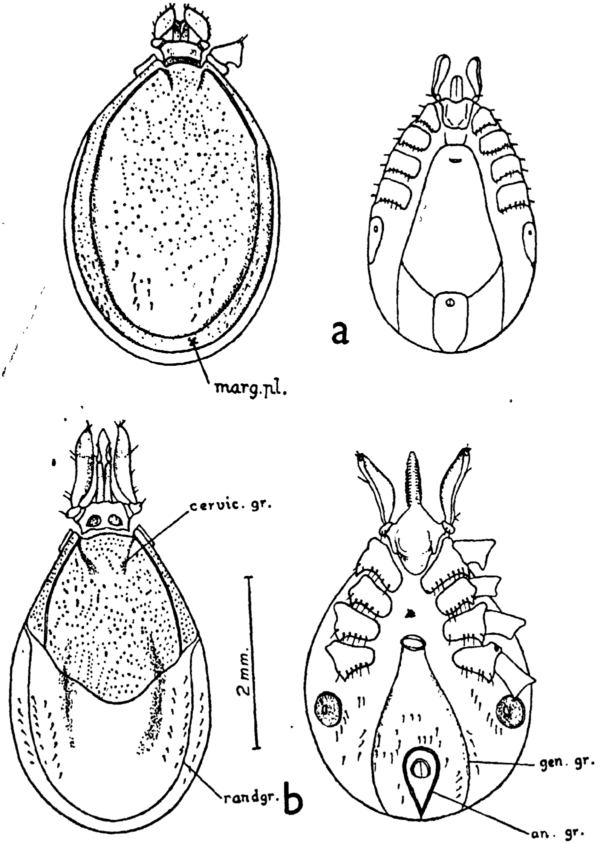

Fig. 130. The scrub or dog tick, *Ixodes holocyclus.* (*a*) Male (dorsal and ventral view); (*b*) female (dorsal and ventral view); *an.gr.*, anal groove; *cervic. gr.*, cervical groove; *gen. gr.*, genital groove; *marg. pl.*, marginal fold; *rand gr.*, marginal groove.

(*After Clunies Ross from Krijgsman and Ponto.*)

complete life cycle may be as long as 741 days, and probably longer.

Under natural conditions all stages will attempt to feed on man, dog, and other domestic animals. Larvae and nymphs may be reared on such hosts as guinea pigs and dogs, but on these animals there is a high mortality. The bandicoot, however, is a very suitable host for these stages.

Adult ticks are most active during spring and summer, but may be present at any time of the year, even in winter, particularly when a few warm days occur. In the warmer months activity ceases during hot, dry periods, and recommences in humid, showery weather.

Importance. Infestation of domestic animals and man frequently results in a condition of paralysis that may end fatally. Sheep, cats, and dogs are particularly susceptible. Among the larger types of animals, paralysis is seen mainly in the calves and foals, though in Queensland fatalities among grown cattle have also been observed. Several cases have been reported in children. Paralysis may follow infestation with the adults, nymphs, and larvae and is most frequent during the late winter and spring, though cases may occur at any time of the year should warm and moist conditions occur. In the case of larvae, the condition has been reported only from experimental infestations of guinea pigs, when 500 larvae have been rapidly fatal. Nymphs will also paralyse guinea pigs, twelve to twenty-four being fatal, and heavy infestations may cause paralysis in dogs, though this appears to be a milder type than that brought about by adults. In the case of adults, paralysis is associated only with female ticks, and with small animals such as the dog and cat one female may be sufficient to cause this condition. Cases of paralysis in grown cattle have been reported from the Yarraman and Boonah districts of Queensland, when heavy infestations of ticks have been present.

Tick paralysis has been studied mainly in dogs in which the period between the attachment of the tick and the onset of symptoms apparently depends on the rate and stage of engorgement. The first symptoms are not seen until at least four to five days after attachment, and they may be delayed as long as thirteen days.

The first definite symptom is a slight incoordination of the hindquarters that rapidly becomes more marked. It later extends to the forelimbs, and the animal is unable to stand. In fatal cases the muscles of the head, neck, tongue, and larynx are involved, death eventually occurring from respiratory paralysis. Animals may recover without treatment, but the more rapid the onset of the symptoms, the more severe is the attack and the less favourable the prognosis.

Animals that recover develop an immunity, which in the absence of further infestation may last as long as eight months. Paralysis can also occur among the tick's marsupial hosts, and the apparent immunity seen among these animals is, no doubt, due to the development of an immunity by natural infestation.

Paralysis is associated with a toxin of unknown type, which is apparently identical with the toxin injected by other species of ticks causing paralysis in other parts of the world, such as *Ixodes rubicundus* and *I. pilosus* in sheep in South Africa, *Dermacentor andersoni* in dogs, sheep, cattle, etc., in North America, *I. ricinus* in sheep in Crete, *Hyalomma* sp. in sheep in southern Yugoslavia, and *Haemaphysalis cinnabarina punctata* in calves, sheep, and goats in Serbian Macedonia. In all cases only the females are concerned.

Paralysis has also been reported from the argasid ticks, *Argas persicus* in fowls in Africa and *Ornithodoros lahorensis* in sheep in Central Asia, but here the clinical picture is different, and though little information is available it seems fairly definite that the toxin responsible is different to that of ixodid ticks.

Studies in Australia indicate that the toxin is elaborated in the salivary gland of *I. holocyclus*, and the onset of paralysis is coincidental with the last rapid engorgement of the tick, when a copious flow of salivary fluid, and also of the toxin, enters the wound.

Reports from oversea countries, however, claim that an identical condition of paralysis may be set up by injecting emulsions of eggs into the host and that the toxin occurs in the eggs of many species of ixodid ticks, even in species not associated with paralysis under natural conditions, such as species of *Boophilus* and *Rhipicephalus*. The formation of the toxin in the female is considered to be associated with egg production, and the more advanced this is the more toxin is present. The toxin reaches the salivary glands late in the period of feeding and differs in its virulence from species to species. That of *I. holocyclus* is probably the most virulent and can be passed to the larvae and nymphs, a condition that does not occur with other species.

The pathology of tick paralysis shows degenerative changes in the central nervous system, which accounts for the progressive paralysis and interference with respiratory activities.

Infestation by the larvae and nymphs of *I. holocyclus* can be extremely irritating, and in the case of man, attachment by an adult is frequently followed by marked and extensive oedema. *I. holocyclus* is also capable of transmitting Q fever (*Coxiella burnetii*) and is probably of importance in the dissemination of this disease among the native reservoir hosts and cattle.

Control. Ticks attached to dogs will be killed, and protection from reinfestation given for about four days, by dusting the animal with derris powder or by washing in an infusion of derris in water. The treatment must be done thoroughly. The infusion is made by soaking 1½ ounces of derris powder in 1 gallon of water for about twelve hours and, just prior to use, adding sufficient soap to give a good lather. It is allowed to dry on the animal's coat. The inside of the ears, and the parts around the eyes and mouth and between the toes are carefully examined, and any tick present is removed by a slow, gentle pull, or snipped out with a small piece of skin. In ticky country and particularly during periods of tick activity, treatment should be repeated every seven days. Derris should not be permitted to come into contact with the animal's eyes.

Little work has been done on the value of any of the chlorinated hydrocarbon insecticides in the control of *I. holocyclus*, but their high efficiency in killing other species of ticks and in protecting against reinfestation indicates that similar results can be expected against the scrub tick. A wash with a concentration of 1 per cent DDT or 0·1 per cent gamma BHC should give good control. The intervals between treatments should be no longer than seven days.

Where treatment with an insecticide is not carried out, the dog should be carefully examined every day and any ticks removed, particular attention being given to the inside of the ears, and the parts round the eyes and between the toes. Dogs may also be protected by injections of antitoxic serum, which gives immunity for about fourteen days.

Treatment of affected dogs is based on the immunity that occurs in animals surviving infestation. A very good hyper-immune serum has been developed, which is particularly effective if used during the early stages of the disease. The serum which is prepared by the Commonwealth Serum Laboratories, is obtained from dogs that are immunized by employing gradually increasing degrees of engorgement and numbers of ticks.

The control of ticks on sheep, cattle, horses, and pigs presents a difficult problem. During periods of tick activity, spraying or dipping at regular intervals with 1 per cent DDT or 0·1 per cent gamma BHC should be beneficial. The intervals between treatments can be determined only by experience, since no critical data is available by which they can be established.

The tick populations depend largely on the presence or absence of marsupials, particularly bandicoots. The clearing of scrub and undergrowth that provides shelter for these hosts, the application of measures for their eradication, and the fencing of pastures with suitable netting, will do much to reduce the chances of infestation among domestic animals.

The New Zealand Cattle Tick or Bush Tick (*Haemaphysalis bispinosa* **Neumann**). The female of this species is, when fully engorged, about the same size as the common cattle tick, *Boophilus microplus*, from which it may be distinguished by the dark-brown legs, the laterally projecting palps, the absence of eyes, and the presence of festoons and a well-marked anal groove (Fig. 132). It differs from other species of *Haemaphysalis* recorded from Australia by the possession of a conspicuous dorsal spine on the posterior border of article 3 of the palps (Fig. 131).

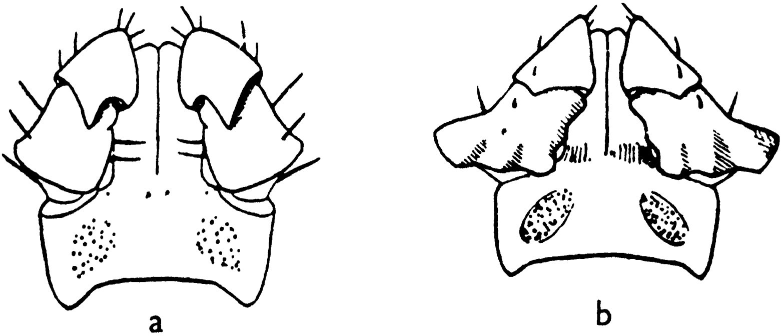

Fig. 131. (*a*) Capitulum of *Haemaphysalis bispinosa* (dorsal view); (*b*) capitulum of *H. bancrofti* (dorsal view).

(*After Nuttal et al.*)

H. bispinosa has a wide distribution throughout the East and is known from India, Burma, the Malay States, the East Indies, China, and Japan. It is also present in British East Africa, Fiji, Australia, and New Zealand. In Australia it is seen in south-eastern Queensland and the northern coastal areas of New South Wales, occasionally extending inland to the Divide and southwards beyond Sydney.

Habits and Life History. In Australia *H. bispinosa* is recorded from man, cattle, the horse, the sheep, the pig, and the dog. In other countries it also attacks the cat, certain wild mammals and birds, and poultry.

It is a common tick on cattle in the North Auckland Peninsular district of New Zealand. This is a three-host tick and the duration of the various life cycle periods is given below:

Period	*Days*
Pre-oviposition	10 to 60
Oviposition	20 to 30
Incubation	37 to 90
Larval engorgement	3 to 9
Larval moult	19 to 22
Nymphal engorgement	5 to 7
Nymphal moult	23 to 95
Female engorgement	7

Males are scarce and there is some evidence that reproduction may be mainly by parthenogenesis. Unfed larvae are able to survive up to 217 days, unfed nymphs up to 263 days, and unfed females up to 249 days. In New Zealand the species over-winters as nymphs. In late winter and early spring these attach, and by midsummer the populations consist mainly of attached adults. Larvae are plentiful during the late summer, and during the autumn most of them have left their host to give rise to nymphs.

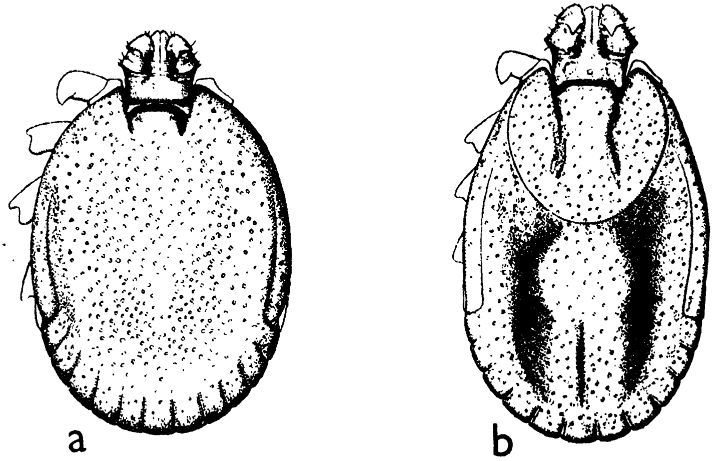

Fig. 132. The New Zealand cattle tick or bush tick, *Haemaphysalis bispinosa.* (*a*) Male (dorsal view); (*b*) female (dorsal view).

(*After Krijgsman and Ponto.*)

Importance. Heavy infestations are seen mainly on cattle. Occasionally horses, sheep, and dogs may also be severely attacked. Infestation of sheep may be regarded as relatively unimportant, since very few sheep are maintained in those districts of New South Wales and Queensland where this tick occurs. Heavy infestations on cattle may cause a condition of "tick worry", particularly in young animals, the principal symptoms of which are anaemia through loss of blood, and losses of condition. Ticks are most commonly found on and around the ears, on the back of the neck, around the anus, on the tail and escutcheon, and inside the flanks. Frequently, large numbers are seen inside the ears. As is the case with the common cattle tick, *Boophilus microplus*, serious damage may be done to the hide by tick bites. On horses the ticks attach mainly in the region of the mane, tail, chest, inguinal region, and in the ear. The irritation may be severe, particularly where larvae and nymphs are concerned.

H. bispinosa is a vector of *Babesia gibsoni* of dogs in India, a disease that does not occur in Australia. It has been shown, however, to be an experimental vector of Q fever (*Coxiella burnetii*) of man and may possibly be of some importance in the epidemiology of this disease. Experiments in Australia have shown it to be incapable of carrying redwater (*B. bigemina*) of cattle. It is, however, a suspected vector of *Theileria mutans* in these animals.

Control. Since *H. bispinosa* is a three-host tick, the routine treatments with arsenic (0·2 per cent As_2O_3) as employed for the control of the common cattle tick, *Boophilus microplus*, are of little value. DDT, as used against *B. microplus* (0·5 per cent (see p. 231)) appears promising, but it may be necessary to employ higher concentrations (1·0 per cent DDT) and a shorter dipping interval to obtain effective control. BHC (0·05 per cent gamma isomer) would probably kill the majority of attached ticks, but the lower degree of residual toxicity possessed by this insecticide makes it less promising than DDT.

The Wallaby Tick (*Haemaphysalis bancrofti* **Warburton and Nuttall**). This species is confined to Australia and at present is reported only from Queensland, where it ranges from the Atherton Tableland to the south-eastern districts and as far west as Emerald and the Darling Downs. It is primarily a marsupial tick of scrub country, and is by no means uncommon on cattle and horses. It has been seen only in small numbers and does no harm, so far as is known, though its role as a possible vector of the cattle tick fevers has not been determined. Its life history is unknown.

H. bancrofti may be distinguished from the common cattle tick, *Boophilus microplus*, by the dark-brown legs, the absence of eyes, and the presence of festoons and a conspicuous anal groove. The palps are strongly salient laterally, much more so than in *H. bispinosa*, from which it also differs in the absence of a strong dorsal spine on the posterior border of the third palpal article (Fig. 131).

The Brown Dog Tick (*Rhipicephalus sanguineus* (**Latrielle**)). This species is a common and widely distributed pest of dogs throughout tropical and sub-tropical countries and is known from the United States, Central America, the West Indies, Brazil, Africa, southern Asia, southern Europe, the East Indies, New Guinea, and Australia. In Australia it is recorded as far south as Sydney, but towards the southern limit of its distribution it becomes extremely rare. It is widely scattered and very prevalent throughout Queensland, the Northern Territory, and north-west Western Australia, probably being most abundant in the drier inland areas. The female tick when fully engorged with blood is

H

about 12 millimetres in length and bluish-grey to reddish in colour, with brown legs. The male is smaller than the female, uniformly dark-brownish in colour, and is usually seen crawling actively in the coat of its host.

R. sanguineus may be readily distinguished by its brown legs, the hexagonal basis capitulum, the non-salient, short palps, the presence of eyes and festoons, and deeply bifid first coxae. The anal groove is behind the anus (Fig. 133).

Habits and Life History. The brown dog tick may be regarded as a domestic species whose principal host is the dog. Cats and wild mammals, particularly carnivores, may also be attacked. Occasionally ticks are

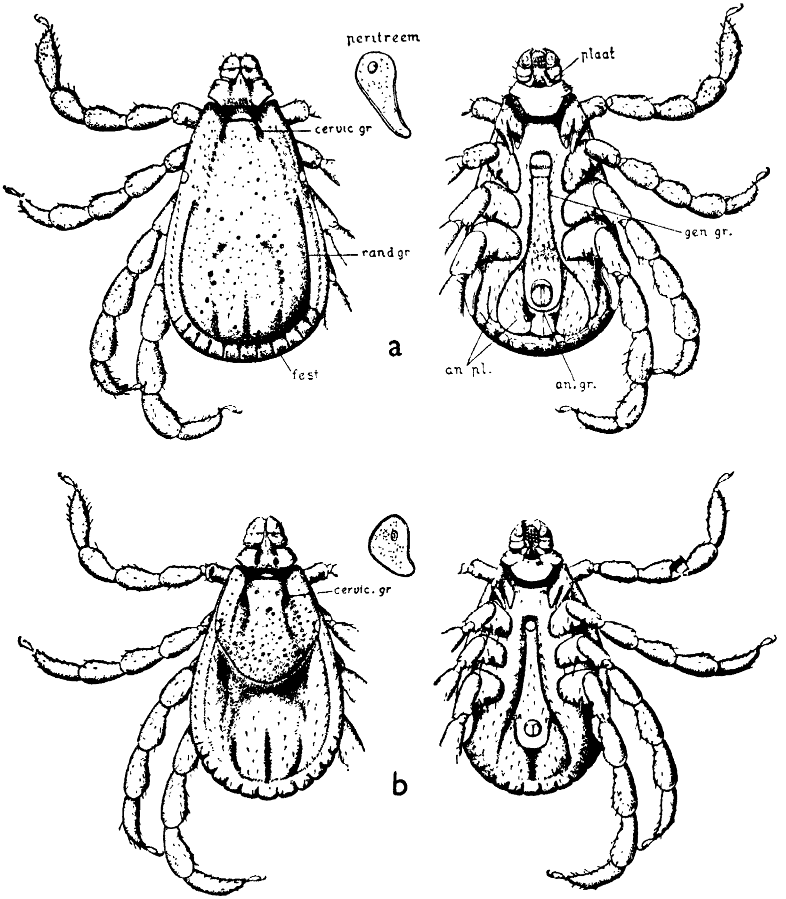

Fig. 133. The brown dog tick, *Rhipicephalus sanguineus*. (*a*) Male (dorsal and ventral views); (*b*) female (dorsal and ventral views); *an gr*., anal groove; *an.pl.*, anal plates; *cervic. gr*., cervical groove; *fest*., festoons; *gen. gr*., genital groove; *peritreem*, spiracular plate; *rand. gr*., marginal groove.

(*After Krijgsman and Ponto.*)

found on cattle, sheep, and goats, and on rare occasions will attack man. It is a three-host tick and the duration of the various life cycle periods is given below:

Period	*Days*
Pre-oviposition	3
Incubation	17 to 60
Larval engorgement ..	2 to 7
Larval moult	5 to 23
Nymphal engorgement ..	4 to 9
Nymphal moult	11 to 73
Female engorgement ..	6 to 30

The average number of eggs laid by each female is 3000. Unfed larvae may survive as long as eight and a half months, unfed nymphs as long as six months, and unfed adults as long as nineteen months.

Importance. This tick is a serious pest of dogs throughout the subtropical and tropical areas of Australia. Heavy infestations are common and lead to such worry and irritation as to impose a great drain on the animal's vitality. This is particularly so among sheep and cattle dogs in the pastoral areas where the tick breeds very rapidly. It may attach to any part of the body, but is most frequently seen in large numbers on the forequarters and in the ears, where it may cause serious trouble. The immature stages are most abundant on the neck.

Sometimes when infested dogs are permitted the run of the house, ticks become an important household pest, though they seldom attempt to attack the human occupants.

Among the diseases of which this tick is a vector (see p. 204), only anaplasmosis of cattle and Q fever of man are known in Australia. The role of *R. sanguineus* in the epidemiology of anaplasmosis in this country is not considered important, for it is an extremely rare tick on cattle, and furthermore is very prevalent in areas in which this disease in unknown. In the case of Q fever it is considered a potential vector only, since it rarely attacks man.

Control. This species may be readily controlled by the following measures:

1. Thoroughly cleaning out the sleeping quarters of the dogs, boiling or burning bedding, and spraying with 1 per cent DDT, 0·1 per cent gamma BHC, or kerosene or fuel oil containing 1 pound of paradichlorobenzene to 1 gallon of oil.

2. Washing all dogs in 1 per cent DDT or 0·1 per cent gamma BHC. Washing is more effective than dusting because it gives a longer period of protection against reinfestation. It must be remembered that the dog tick is a three-host tick whose larvae, nymphs, and adults can survive many months in the absence of a host. Control can, therefore, become satisfactory only when the animals are carefully watched and regularly treated. Preliminary observations indicate that the first two or three treatments are effective at intervals of ten to fourteen days, and that thereafter the intervals between treatments may be gradually lengthened. When washing the dogs it is advisable to prepare a permanent bath, say half a 44-gallon drum, which can then be filled with the DDT or BHC to the required depth. The bath is thereafter maintained simply by adding fresh

insecticide and the necessary amount of water. The animal should be thoroughly saturated to the skin, care being taken to treat the inside of the ears and the area between the toes.

BHC kills the ticks more rapidly than DDT, which may take as long as five to six days. However, DDT gives a longer period of protection.

Some consideration must also be given to the construction of kennels, which should be built of brick or concrete,which enables them to be cleaned easily. All cracks and crevices in which the ticks could shelter should be eliminated.

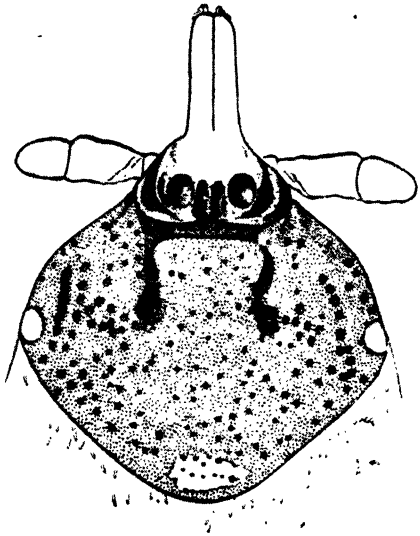

Fig. 134. Capitulum and scutum of the female ornate kangaroo tick, *Amblyomma triguttatum.*

After Robinson.)

Human dwellings that have become heavily infested are best treated by fumigation with potassium cyanide. Otherwise the patient use of DDT or kerosene and paradichlorobenzene sprays (1 pound of paradichlorobenzene to 1 gallon of oil), and the exclusion of all dogs unless employed as traps, is recommended.

The Ornate Kangaroo Tick (*Amblyomma triguttatum* **Koch**). This species is normally a parasite of kangaroos and wallabies, but is not uncommon on cattle, horses, sheep and dogs. It is also recorded from the dingo.

A. triguttatum is an inhabitant of the drier inland areas of Australia, but may be carried into the coastal regions on one or other of its hosts. It is recorded from northern Western Australia, the Northern Territory, Queensland, and north-western New South Wales.

The engorged female tick may attain a length of 20 millimetres and can be recognized by its reddish-brown scutum with a pale spot in the posterior angle and occasionally also in the lateral fields. The porose areas are separated from each other by a double pit-like depression, and from the lateral borders of the basis capituli by a deep, curving groove (Fig. 134). The legs are dark, with narrow white rings at the joints.

The male has an irregular, elongate, pale area in each lateral field of the scutum and a pair of smaller pale spots posteriorly. Sometimes the ornamentation is more extensive and extends to the scapular fields, with small pale areas on the lateral margins and on the festoons.

Beyond the fact that *A. triguttatum* is a three-host tick, nothing is known of its life history.

This tick does not appear to be harmful to the domestic animals it attacks, and heavy infestations have never been recorded. However, it is frequently seen on cattle and horses, and has been mistaken for the common cattle tick, *Boophilus microplus*.

The Cattle Tick (*Boophilus microplus* (Canes)). This is the common tick infesting Australian cattle. It can readily be distinguished from other ticks found on cattle in this country by the presence of eyes, and the absence of festoons and of an anal groove. The mouth-parts are short and the palps non-salient laterally. The fully engorged female is 10 to 12 millimetres in length, and in colour is slaty-grey, sometimes darker, sometimes with yellow or orange markings. The legs are short and pale. The male is only 2 to 2·5 millimetres long, dark brown in colour, and is provided with a small caudal appendage (Fig. 135).

Distribution. B. microplus occurs in Central and South America, the United States (Florida), the West Indies, India, Malaya, the East Indies, the Philippine Islands, New Guinea, the Solomon Islands, Noumea, and Australia. During World War II ticks were introduced into Noumea on infested horses.

This tick is thought to have been introduced into Australia in 1872 on Brahman cattle that were brought from Batavia to the Northern Territory. It remained unnoticed until 1880-1, when heavy mortalities from tick fever occurred in cattle at Glencoe, 104 miles south-east of Darwin. The tick entered Queensland via the Gulf of Carpentaria and then spread south along the stock routes to Longreach and Hughenden (1895), and from there by rail to the east coast. It reached Brisbane in 1899, but did not appear in New South Wales until 1906, when it was observed at Tweed Heads on horses.

It also spread from the Northern Territory along the stock routes into the north-west districts of Western Australia.

In Queensland the tick is now present in all areas where it can permanently establish itself. This includes the whole of the eastern coastal watershed and the area north of a line drawn between Hughenden, Cloncurry, and Camooweal, though infestations are very light and sporadic along the inner edge (Fig. 136). Occasionally outbreaks are reported from farther inland, but owing to the State's control activities, assisted by unfavourable climatic conditions, the tick has never established itself in these areas.

In New South Wales *B. microplus* has been confined to a small part of the North Coast district (Fig. 136). At one time it had spread as far south as Urunga, twenty miles south of Coff's Harbour, but was subsequently eradicated from this area and also from the Grafton-Maclean area. The area now infested includes the whole of the Tweed River and Richmond River watersheds, inland to the Woodenbong-Benalbo-Tabulam districts, an area of approximately 5000 square miles.

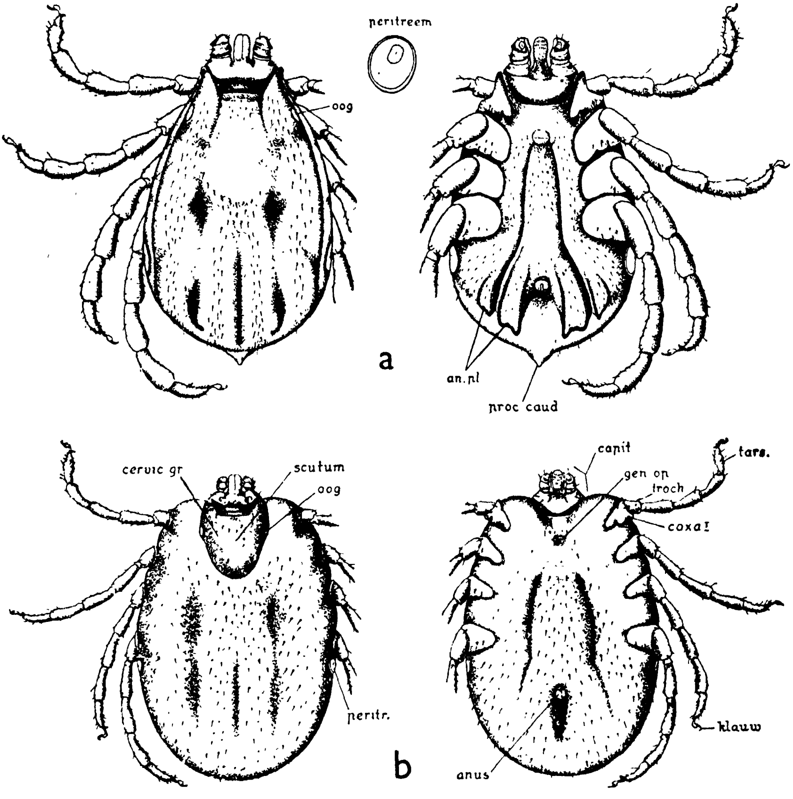

Fig. 135. The common cattle tick, *Boophilus microplus.* (*a*) Male (dorsal and ventral views); (*b*) female (dorsal and ventral views); *an. pl.*, anal plates; *anus*, anal opening; *capit.*, capitulum; *cervic. gr.*, cervical groove; *coxa I*, first coxa; *gen. op.*, genital opening; *klauw*, claw; *oog.*, eye; *peritr.*, *peritreem*, spiracular plate; *proc. caud.*, caudal process; *tars.*, tarsus; *troch.*, trochanter.

(*After Kriigsman and Ponto.*)

In both the Northern Territory and Western Australia the cattle tick has not appeared south of 20 degrees south latitude (Fig. 136). In Western Australia it had been introduced into Fremantle, but failed to establish itself there.

Hosts. In Australia *B. microplus* is recorded from cattle, horses, sheep, the Indian water buffalo, dogs, pigs, Scottish deer, wallaby and kangaroo.

Cattle are the principal hosts, but heavy infestations are also seen on horses, sheep and deer. Scottish deer are common in the Brisbane Valley and the Blackbutt Range in Queensland, and will prove a serious obstacle to any attempt to eradicate ticks from these areas. On horses, sheep, and deer, female ticks develop successfully and lay viable eggs. The mortality rate among ticks infesting the horse is fairly high, particularly in the immature stages. Infestation of dogs, pigs, wallabies and kangaroos is regarded as being extremely rare and unusual, and these animals are of little importance as reservoir hosts.

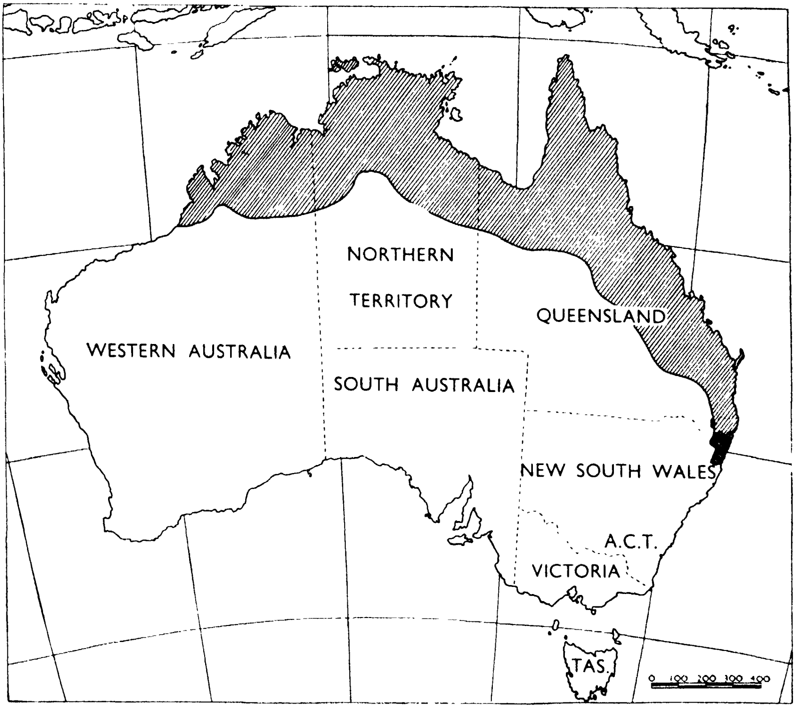

Fig. 136. The distribution of the common cattle tick, *Boophilus microplus*, in Australia. The larger shaded part shows the infested area. The small, darker shaded part shows the areas of New South Wales from which *Boophilus* has been eradicated.

(*After Seddon.*)

The larvae will also attack man, but do not become established. In Brazil, larvae have also been reported from rabbits.

Habits and Life History. B. microplus is a one-host tick. When fully engorged, the female drops from the host and crawls to some sheltered spot in the pasture. She rests for some time and then commences to lay eggs. These are laid in masses of up to 5000, with an average of 3000. As the eggs are deposited the female retreats, leaving a thick trail of them

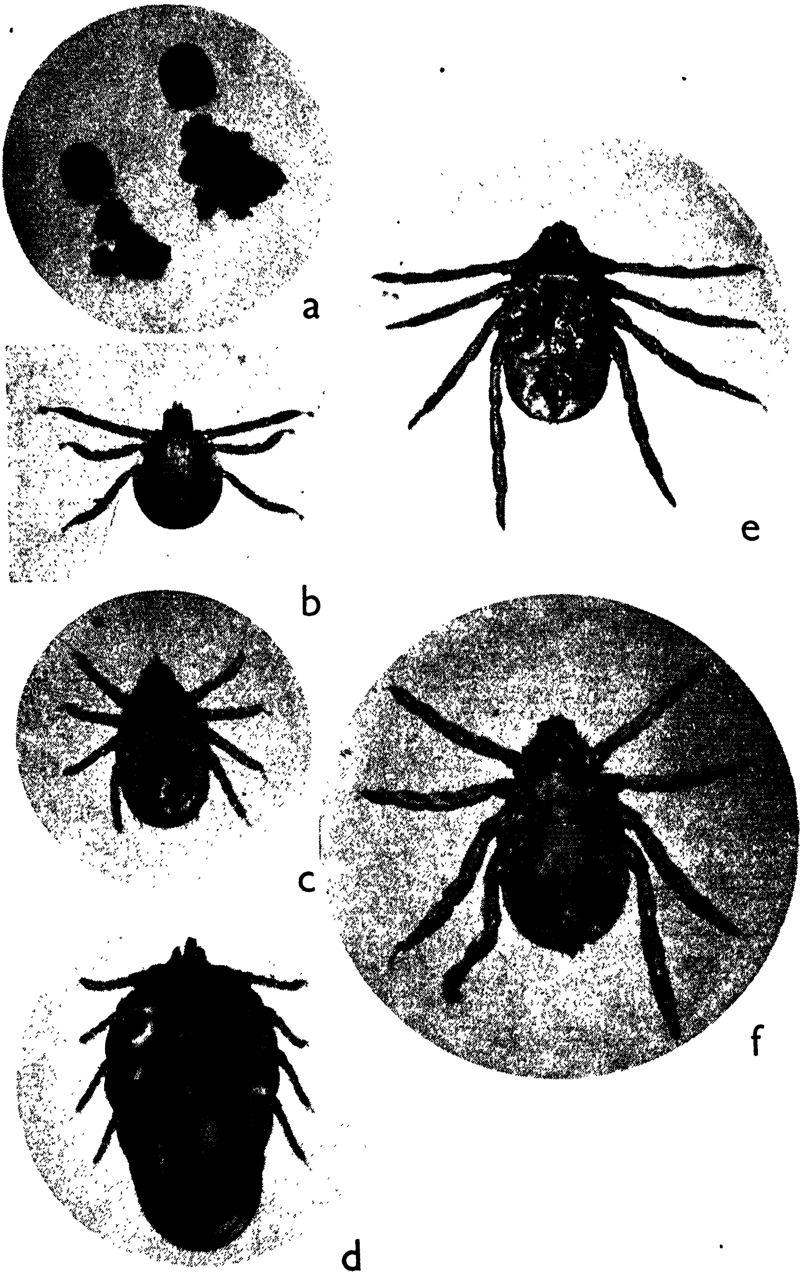

Fig. 137. The life cycle of the common cattle tick, *Boophilus microplus.* (*a*) Female ticks laying eggs; (*b*) newly hatched larval or seed tick; (*c*) newly moulted nymph; (*d*) engorged nymph; (*e*) newly moulted female; (*f*) adult male. (All figures not to same magnification.)

behind her (Fig. 137 (*a*)). Egg-laying completed, the female is now yellow-brown, small and shrivelled, and eventually dies.

The duration of the pre-oviposition and oviposition periods depends mainly on the prevailing temperatures. During summer the former is usually in the vicinity of two to three days, but it may extend over two to three weeks or even longer during winter. Similarly the oviposition period may extend from ten days in summer to several weeks in winter, the optimum range lying somewhere between 76° and 80° F. The ovipositing female tick is very susceptible to low temperatures, and exposure to 20° F. is usually fatal. Semi-engorged females will also lay eggs, but only in small numbers.

The egg is shiny, dark yellowish-brown in colour, ovoid in shape, and measures 0·5 by 0·4 millimetre. Hatching is dependent mainly on temperature. During summer the incubation period is two to three weeks, but it is more protracted during cold weather. At 97° F., for example, eggs will hatch in thirteen days, whereas at 59° F., the lowest temperature at which eggs will develop, hatching is delayed for 114 days. At these temperatures the constant relative humidity must not fall below 70 per cent. The percentage of eggs hatching from the egg masses of single fertilized females varies widely, and may be as high as 98 per cent and as low as 9 per cent. The eggs deposited towards the close of the oviposition period are infertile. Under experimental conditions eggs have survived up to fourteen days' submergence in water, though the percentage survival after this period was poor.

The larva, on hatching from the egg, is very pale, but soon darkens somewhat, the scutum attaining a dark-reddish colour. It measures 0·5 millimetre, increasing to 1·5 millimetres in length as it engorges on the host. It can be readily distinguished from the larvae of other species of ticks by the short mouth-parts, the presence of eyes, and the absence of festoons (Figs. 125 (6), 137 (*b*)). On hatching from the eggs the larvae ascend the vegetation, fences, etc., where they collect in masses, usually on the shady side. They show the greatest activity when disturbed, waving their anterior limbs vigorously in the air, and are ready to swarm on any object that brushes past. This stage can survive up to seven days' complete submergence in water.

Observations of the larvae of *B. annulatus* in the United States show that the period of survival in the field depends on climate and weather. Moisture and cold will prolong survival up to 246 days, while under conditions of dryness and heat this period may be reduced to 100 days. Experimental studies on *B. microplus* in Australia give similar findings, for it has been found that longevity increases with humidity at all temperatures, the optimum humidity being in the range 90 to 95 per cent. The maximum longevity of 218 days is obtained at 59° F., whilst at 95° F. larvae live only 16 days.

Having secured access to a suitable host, the majority of the larvae settle down and commence to feed within a few hours, showing a marked predilection for certain parts of the body, particularly the flank, inguinal region and escutcheon, neck and brisket. Some, however, may wander for up to three days before attaching. The larvae appear to suck lymph only, and in three and a half to seven days (average four days) are fully engorged and ready to moult to the nymphal stage.

The nymph appears one and a half to two and a half days later and usually settles down close to where previously attached, but sometimes it may wander about to an extent indicating that at this period a change of hosts could occur. Nymphs arising from engorged larvae removed from the host will survive up to seven days.

The nymph measures 1·25 to 3 millimetres in length, depending on the state of engorgement. The unfed specimen is light yellow to grey brown in colour, with a light reddish-brown scutum and four pairs of pale, short legs (Fig. 137 (*c*)). The engorged nymph (Fig. 137 (*d*)) is greyish blue, and reaches this stage ten to twenty days after it attached as a larva (average thirteen days). After a resting period of two days the nymph moults to the adult stage, the nymphs giving rise to males being only about half the size of those that produce females.

Males appear first and mating may be seen as early as the fourteenth day of parasitism. The young female has comparatively long legs (Fig. 137 (*e*)) and, like the larva, usually re-attaches at a spot near the previous site of feeding, though some specimens may travel a considerable distance. This stage will also survive up to seven days away from the host. Engorgement is slow for the first three or four days, and then increases rapidly, and full engorgement and dropping from the host occurs 18½ to 37 days, rarely as long as 42 days (average 23 days) after attachment by the larva. The males (Fig. 137 (*f*)) never settle very long in any one place and are usually found attending a female or the larger nymphs destined to become females. Males will live as long as 70 days.

The various life cycle periods are summarized below:

NON-PARASITIC LIFE CYCLE (LABORATORY DATA)

Life Cycle Stage	*Minimum* (*Days*)	*Maximum* (*Days*)
Pre-oviposition	2	27
Oviposition	10	several weeks
Incubation	14	114
Larval longevity	2	218

PARASITIC LIFE CYCLE
(Age in days from attachment)

	Larva			*Nymph*			*Adult*		
	Young	*Medium-sized*	*Engorged*	*Young*	*Medium-sized*	*Engorged*	*Young*	*Medium-sized*	*Engorged*
Minimum	—	—	3½	4½	7½	10	13	17	18½
Maximum	—	—	7	10	15	20	23	—	42
Mean	1-2	3	4	6	10	13	15	20	25

Seasonal Activity. In southern Queensland and New South Wales the low temperatures and dryness of the winters are responsible for a considerable reduction in activity during this period of the year. Ticks commence to reappear in numbers following the spring storms, and infestations are heaviest and most difficult to control during the period from about January to May, depending on the advent and extent of the summer rains. In North Queensland, where the heavy summer rains are usually associated with floods, the tick populations do not usually attain their maximum number until about April-May. Although the winters are dry in this part of the State, heavy infestations may continue throughout this period of the year.

It has been noted that tick populations along the inner edges of the infested areas are light and sporadic. Whilst ticks cannot flourish in these areas during prolonged dry weather, their numbers usually increase during the wet season, but frequently do not attain serious pest proportions unless the summer rains are abnormally high and prolonged.

Importance. The economic loss from *B. microplus* is almost entirely confined to the cattle industry. Horses may be severely irritated, and may lose condition and become dull and listless. Among sheep the tick causes practically no loss, for it does not occur in true sheep country and is seen only among the few animals running on the coast. Infestation is rarely heavy and is usually restricted to those parts of the body that carry no wool.

Among cattle, however, *B. microplus* is a major pest, and within the area of its distribution it is responsible for a heavier economic loss than any other disease. This loss is caused, firstly, through tick infestation *per se*, secondly, through tick-borne diseases, and, thirdly, through the expenditure required for tick control.

TICK INFESTATION OF CATTLE

Cattle carrying a few ticks suffer little harm, but heavy infestations cause severe irritation and the skin becomes inflamed, corrugated, and scaly (Fig. 138). Secondary infection followed by sloughing of large areas and ulceration (tick sores) is not uncommon. Owing to the blood-sucking activities of the parasites some degree of anaemia may occur, the severity of which depends on the degree of infestation and the ability of the animal to replace the blood taken by the ticks. There may be rapid loss of condition, milk production may fall, and infested animals may become dull and listless. This condition is known as tick worry or tick poverty. It has been estimated that each female tick ingests approximately 1·5 millilitres of blood during her parasitic life. An infestation of 5000 females is by no means uncommon, and on this basis this number would remove nearly one and three quarter gallons of blood every three weeks. Really heavy infestations have been estimated to comprise as many as 20,000 or more ticks, so it is not surprising that animals carrying large numbers of ticks will die unless relieved. Undoubtedly, also, some type of toxin is injected by the ticks when feeding. Nymphs, for example, are responsible for temporary oedematous swellings, and emulsions of the eggs, if inoculated into guinea pigs, are rapidly fatal. Just how this "toxin" contributes to the general clinical picture of tick infestation is unknown.

Cattle hides are permanently damaged by tick bites and are considerably depreciated in value. Recent data are not available, but in 1915, when hides reached a high price, it was estimated that losses from this cause were in the vicinity of £140,000 for Queensland alone.

Under Australian conditions the heaviest losses from tick infestation occur on the large undeveloped properties in northern Australia where, for the most part, ticks are not controlled. In the rest of the tick-infested area cattle are under much closer supervision and are subject to regular treatment. Even so, heavy infestations are common and are an ever-present menace to the health of the animals.

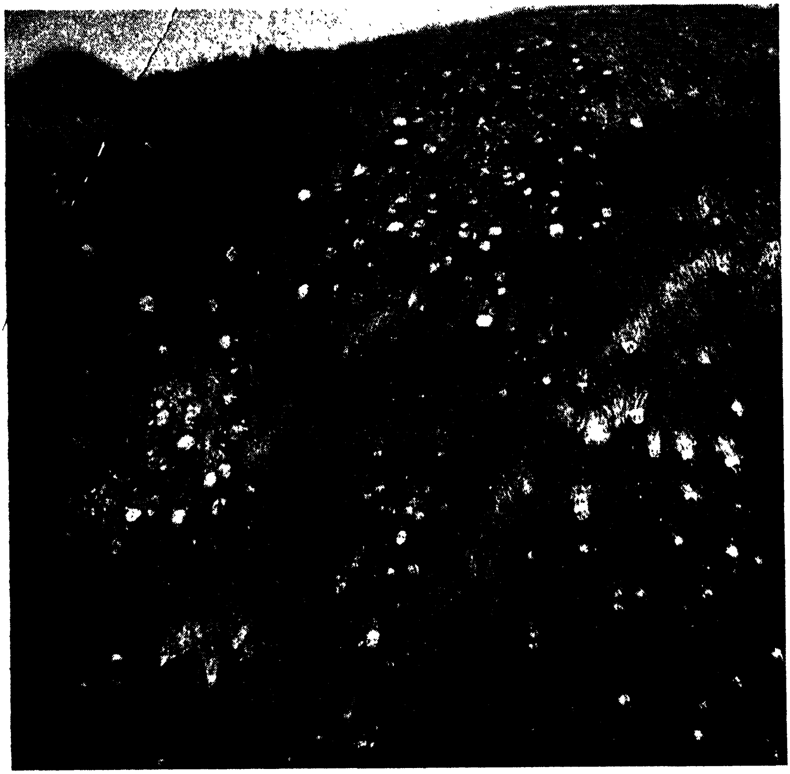

Fig. 138. Heavy infestation of cow with *Boophilus microplus.*
(*After Keith.*)

TICK-BORNE DISEASES OF CATTLE

Eight protozoan organisms, namely *Trypanosoma theileri, Epirythrozoon wenyoni, Bartonella bovis, Theileria mutans, Babesia bigemina, B. argentina, Anaplasma marginale,* and *A. centrale,* and a spirochaete, *Borrelia theileri*, are recorded from the blood of Australian cattle. *Trypanosoma theileri*, *E. wenyoni*, and *E. bovis* have apparently little pathogenicity and their vectors are unknown. *Babesia bigemina*, *B. argentina*, and *A. marginale* are all highly pathogenic and are transmitted by *Boophilus microplus*. In South Africa, *Theileria mutans* is regarded as occasionally pathogenic, causing pseudo East Coast fever, *B. decoloratus* being a vector. It is widespread throughout the tick areas of Australia and is presumably carried by *B. microplus*. Since, however, it also occurs in cattle in clean country, it must have other vectors as well, and *Haemaphysalis bispinosa* has been suspected as one of these. *T. mutans* is not usually considered pathogenic in Australia, though it is sometimes associated with anaemia in young animals. *Borrelia theileri* is also probably carried by *B. microplus*. *A. centrale* was introduced from South Africa for "immunizing" cattle against *A. marginale*. *Babesia bigemina* and *B. argentina* are widespread throughout the tick areas of Queensland, the Northern Territory, and Western Australia, and cause redwater or tick fever, a serious and frequently fatal disease. Queensland experience indicates that *B. argentina* is the more common organism, outbreaks due to *B. bigemina* being comparatively rare. In New South Wales, tick fever is uncommon and outbreaks are few. This is due, firstly, to the fact that when introduced into this State ticks were free of this disease because they were on horses, secondly, to the action taken by the authorities to prevent the introduction of carrier animals, and, thirdly, to the efficient manner with which the few outbreaks have been controlled.

A. marginale causes anaplasmosis or gall sickness. It probably has a similar distribution to the causal organisms of tick fever, but for some unknown reason outbreaks are comparatively infrequent, even in areas where the tick populations are heavy.

When ticks first spread from the Northern Territory throughout Queensland and Western Australia, losses from redwater were severe. They have never reached such serious proportions since then, because cattle that recover from redwater remain "immune" to further attacks, provided they are continuously infested by ticks carrying the organisms. Furthermore, calves born in tick fever areas are usually only mildly affected and thereafter are also "immune" for life. Thus redwater is now of little importance in areas where the disease has occurred and where ticks are present throughout the year in sufficient numbers to maintain this "immunity". Sometimes an occasional animal may show clinical symptoms when, for some reason or other, the balance between the host and the parasite is upset.

Where tick infestation is light and sporadic, animals are likely to lose their "immunity" and serious mortalities may follow when the ticks become numerous. Similarly, heavy losses may occur among animals moving from "clean" to ticky country. In such instances, however, animals may be immunized by inoculation with blood taken from a carrier or "bleeder". This "vaccine" contains *B. bigemina*, *B. argentina*, and *A. centrale*, the latter for protection against *A. marginale*. The reaction to the tick fever organisms is controlled by such drugs as Acaprin, Babesan, Pirevan, and Piroparv.

Boophilus microplus is also a vector of Q fever (*Coxiella burnetii*), of which cattle may be a reservoir host.

Control of the Cattle Tick

Expenditure Involved in Control. To maintain tick populations on a reasonably low plane, animals must be dipped or otherwise treated regularly in arsenic, DDT, or BHC. In addition to the capital involved in the construction of plunge dips and spray races and in the purchase of insecticide, the grazier in heavily infested areas finds that during a large part of the year the major portion of his time is occupied with mustering and dipping.

The infested States have to provide staff and facilities to ensure that cattle moving from ticky to clean country are free from ticks and, in New South Wales, that effective control within the infested area is maintained. Queensland has to provide facilities for "immunizing" cattle moving from clean to ticky country. The expenditure involved in these measures is enormous, and in New South Wales alone it amounts to about £450,000 annually.

Until recent years arsenic was the only insecticide available for routine control of cattle ticks, but it now tends to be displaced by the chlorinated hydrocarbons. Considerable work has been done with DDT and BHC, and their role as highly effective tick-destroying agents has been established. Chlordane, dieldrin and toxaphene are also highly lethal to ticks and, like DDT and BHC, they afford a beneficial period of protection against reinfestation. But much remains to be done before these two compounds can be recommended for practical control conditions. E 605 is also highly effective, but its toxicity to warm-blooded animals is a serious disadvantage.

Arsenic. Arsenic is employed as a watery solution of sodium arsenite containing 0·2 per cent As_2O_3, and has been in use against ticks for over fifty years. Its value against these parasites was first recognized by Mr Mark Christian, who charged the first dipping vat in the Rockhampton district of Queensland. Arsenic was later used in South Africa and then in the United States.

In general, arsenic is a highly effective toxicant and gives good tick control, though more than one treatment is required to kill all ticks, the engorged stages in the life cycle being least susceptible. However, its efficiency over a long period of treatment can be measured by its successful employment for the now almost complete eradication of ticks from the United States where, in 1906, 741,515 square miles were under quarantine because of *B. annulatus*. Arsenic was similarly responsible for the eradication of ticks from the Urunga and Grafton-Maclean districts in New South Wales.

During the past fifteen years, however, control with arsenic has become less effective in certain areas, because of the appearance of a strain of "arsenic-resistant" tick. The term "arsenic-resistant" implies that greater numbers of ticks survived treatment, despite a decrease in the interval between the treatments, and the use of concentrations, in some cases up to nearly 0·4 per cent As_2O_3. Arsenic-resistance in Australia has been seen only in Queensland, where it has been reported from various localities throughout practically the whole of the tick area. The phenomenon is also recorded from South Africa with *B. decoloratus* and from South America with *B. microplus.*

Against susceptible strains of ticks, arsenic has several pronounced advantages. Besides giving effective control, it is cheap and the wash is easily prepared. The concentration of the wash may, furthermore, be readily determined by a dip-side chemical test. Its disadvantages are inherent in its highly poisonous nature. Cattle that are dipped in over-strength washes, or overheated during or shortly after dipping, or dipped in showery, humid weather, are likely to "scald" badly and may die. Thousands of cattle throughout the world have died because of carelessness in disposing of the wash when the dip is being cleaned, or in leaving the containers and mixing vessels lying about.

The sodium arsenite in the dip may also oxidize to sodium arsenate and lose its efficiency. This occurs particularly when the dip is left idle for any length of time. Oxidation is caused by certain bacteria, and can be prevented by covering the dip fluid with a thin layer of oil or with boards. Once oxidation has taken place, the sodium arsenate can be reduced to sodium arsenite by the addition of molasses, lactose or skim milk. The addition of these substances encourages the action of another series of bacteria that are responsible for the reduction of the arsenate to the arsenite. The dip-side iodine test for As_2O_3 will determine the amounts of molasses or skim milk to be added.

For many years the addition of adjuvants to sodium arsenite was considered to increase its efficiency through better wetting properties, and Stockholm tar, bone oil, potash soap, tallow, and other materials were included in official formulae. However, it is now recognized that such materials are not necessary.

DDT and BHC. The fact that neither DDT nor BHC are soluble in water, and dissolve only in certain organic solvents, has proved a serious obstacle to their use in dipping vats under routine control conditions. Dips rapidly become foul through contamination with earth, dung, and urine when they are in regular use, and under these conditions there is considerable danger that emulsions may "crack" and liberate quantities of an irritant solvent. Dispersable powders have the disadvantage that the insecticide particles sink to the bottom fairly rapidly. Much of this material quickly becomes unavailable, and even those particles that can be dispersed by the movement of cattle through the wash do not give an effective concentration until, in some cases, as many as fifty animals or more have passed through. There is no evidence that "stripping" occurs as it does when sheep are dipped. Australian experience, however, shows that a special proprietary DDT formulation known as Rucide overcomes most of the difficulties. This preparation on being heated and poured into water forms an extremely fine suspension, some of the mixture probably being colloidal in nature. Vats charged with Rucide have retained their high toxicity to ticks for periods of several years. It does not mix well with hard water, but in such cases the water can be softened by the addition of a water softener, Calgon for choice, the amount added to the water depending on the degree of hardness of the water.

DDT is used at a concentration of 0·5 per cent para para isomer. Its efficiency against ticks is high, and its residual toxicity keeps cattle free from reinfestation for periods of seven to fourteen days. As with arsenic, the engorged stages in the life cycle are least susceptible. DDT kills slowly, and ticks may remain alive for as long as five to seven days after treatment. Females that survive may lay viable eggs. The best results are obtained with animals in good condition, when two dippings at an interval of three to five days may be relied upon to kill all ticks.

BHC is employed at a concentration of 0·05 per cent gamma isomer. Its efficiency is higher than that of DDT at a concentration of 0·5 per cent para para isomer, and the BHC kills much more quickly, most ticks being dead within twenty-four hours. Its residual toxicity, however, does not last beyond three to five days. With this compound also, fewer female ticks survive and the number laying viable eggs is small. There is some evidence, however, that BHC dips may, in time, show a loss in biological efficiency and also that ticks may become resistant to this insecticide.

Although DDT and BHC may not give as high a kill of ticks as arsenic, their residual toxicity is a decided advantage, for with arsenic this does not exceed a few hours. Other advantages over arsenic are their effectiveness against arsenic-resistant strains of ticks, and the absence of toxicity to cattle under routine dipping conditions. At present, however, the grazier has no ready way of ascertaining the concentration of the wash, other than by following the instructions of the manufacturer in preparing the wash and observing its effects on the ticks.

Both compounds are comparatively costly, and the expenditure per head in preparing and maintaining the wash is about eight to ten times that of arsenic. It must be remembered, however, that fewer treatments are required each year, owing to the high kill of ticks and the long period of protection from reinfestation, during which large numbers of larvae are killed as they attempt to attach. This is particularly so with DDT, of which four to six treatments a year give effective control, as compared with nine or more treatments with arsenic. Mustering costs are therefore much lower and there is less wear and tear on the yards.

The Application of Insecticides. The intervals between treatments depend on whether treatment is employed for (*a*) routine control of ticks on properties in the infested area; (*b*) cleansing of cattle moving from ticky to "clean" or uninfested country; or (*c*) eradication.

Routine Control of Ticks. Except in New South Wales, the control of ticks on any property is, for the most part, left to the discretion of the owner. In such cases treatments are applied solely to prevent the ticks from attaining serious proportions, at the same time—particularly in marginal areas—avoiding reducing the populations to such a low plane as to encourage outbreaks of tick fever. During the season of greatest activity the intervals between treatments are about three weeks with arsenic, perhaps a little longer with BHC, and up to five or six weeks with DDT. During the winter the intervals may be extended to six to eight weeks with arsenic and up to three months or more with DDT.

Tick control is under Government supervision in New South Wales and arsenic is the only insecticide in use. Cattle are inspected every twenty-eight days and there is a 28 day-interval between dippings. In the Richmond and Tweed areas, nine dippings are enforced between September and June. In the less heavily infested western areas the number of dippings is reduced to seven or five between December and June. Milking herds are dipped only if infested, when they are given three treatments at fourteen day-intervals. Tick-fever outbreaks are treated by two dippings with a seven-day interval, followed by dippings at fourteen-day intervals for twelve months.

Movements of Cattle from Ticky to Clean Country. The regulations concerning the travelling of cattle from ticky to clean country vary from State to State, but, in general, where arsenic is used such cattle must have two to three extra dippings at a five- to ten-day interval and be clean prior to the second dipping, and must move within a short time after the last treatment.

In Queensland cattle movements of this type are made through "cleansing areas", which are located on the margin of the infested country. Owing to the difficulty experienced in Queensland with arsenic-resistant ticks, DDT (0·5 per cent para para isomer) is used in the cleansing dips, two treatments at an interval of three to five days usually being effective.

Horses, mules, asses, and in New South Wales, sheep also, are treated.

Eradication. No attempts have yet been made to use DDT or BHC for eradication purposes. The interval between dippings is fourteen days with arsenic. This period ensures that no larvae attaching since the previous treatment can reach the engorged-female stage to drop off and lay eggs, a minimum period of eighteen to nineteen days being required to attain this stage of development.

The fourteen-day interval was used in the eradication of *Boophilus annulatus* from the United States, and the duration of the dipping programme in any district was dependent on the time of the year when eradication commenced. Best results were obtained if the first treatments were carried out in March, which is the beginning of the period in the United States when tick development is most rapid and when the parasitic life cycle and survival in the pastures are the shortest. Dipping commenced then and continued until November gave complete eradication. Horses, mules, and asses were also treated. Deer, when reservoir hosts, were killed or driven from the area.

The New South Wales system has been based on American experience. In the Coff's Harbour and Maclean-Grafton areas, which are now free from ticks, dipping at fourteen-day intervals was carried out for ten months, commencing in September. In the Woodenbong-Benalbo area, however, ten months' treatment failed.

Other Control Measures. These include vacating pastures for a sufficient period to starve out the larvae, and the breeding of tick-resistant animals.

Vacating Pastures. This measure was employed in areas in the United States where the country was too rough to permit regular treatment of all hosts. The pastures were left vacant for periods of five and a half to ten months, depending on the locality and the season of the year, the minimum period coinciding with seasons of low rainfall and high temperatures. Rotation of pastures was sometimes combined with vacation of pastures, when the cattle were freed by moving them to a series of clean fields.

Tick-Resistance Among Individual Animals and Breeds. There seems to be no doubt that some animals are highly resistant to ticks and carry only a few parasites, whilst their herd-mates are heavily infested. Some breeds, for example, Jerseys and Friesians are considered more resistant than others. Zebus and Afrikander cattle (*Bos indicus*) are highly resistant, and the introduction of zebus into tropical Australia for interbreeding with British breeds of beef cattle has as one of its objectives a cross that inherits this factor.

Little attention has been given to the phenomenon of tick-resistance in cattle. There is some degree of resistance exhibited even by apparently susceptible animals, for a high mortality among larval and young adult ticks is a normal process, at least in the case of *B. microplus*.

According to South African work, resistance to ticks among cattle is associated with the thickness of the skin and type of coat. Afrikander cattle are resistant to infestation and have a thick, loose skin and a fine glossy coat, whereas susceptible British breeds have thin skins and a longer and denser coat.

Animals that are tick-resistant apparently maintain the condition from birth and do not acquire it as a result of exposure to infestation.

APPENDIX

COLLECTION AND PRESERVATION OF INSECTS, MITES AND TICKS

An accurate identification of any insect, mite, or tick can be made only after the specimen has been captured and prepared for examination. The specimen is preserved and stored with data giving the name of the host, locality, date of capture, collector's name, and any other information of importance. Where such data has not been recorded, a specimen is worthless.

WINGED INSECTS

Winged insects may be captured in an entomological net, which consists of a cone-shaped bag about two feet long, threaded on a metal or wooden ring about one foot in diameter, and wielded by a handle of convenient length. The bag is made of bolting silk or good quality fine mosquito-net, reinforced with a strip of strong calico where it is threaded on the ring. A short slit is left in the calico strip and net to enable the net to be slipped on and off the ring. The insect is captured by a sweeping motion, or, when convenient, by placing the net over it with the apex held away by the free hand. In either case the insect eventually flies into the apex of the net and is confined there by a quick flick of the wrist, which throws the apical portion of the net across the ring.

Biting species may also be taken in glass tubes, which are carefully placed over them while they are feeding.

A suction bottle is a handy piece of equipment for capturing small insects after they have alighted on the host, or are resting on walls and similar places. Two pieces of glass tubing are passed through a tightly fitting cork of a convenient-sized clear glass bottle or tube. The inlet tubing is bent at right angles and enters the bottle to near its bottom. The outlet tube enters to just below the cork and here it is covered with a piece of fine gauze or net to prevent the insects from being sucked through to the mouth. A piece of rubber tubing is attached to both pieces of glass tubing to permit flexibility of the apparatus when in use.

A quiet cow or horse is a good bait for biting flies, which are more readily seen if the animal's colour is white.

Adults may also be bred from larvae and pupae. Bred adults should not be killed for several hours after emergence, up to twenty-four hours if possible, for otherwise they become shrivelled and distorted when mounted. For breeding methods the reader is referred to *Culture Methods for Invertebrate Animals* by Paul S. Galtsoff *et al.* (1937), Comstock Publishing Company, New York. Types of entomological equipment are dealt with in *A Manual of Entomological Equipment and Methods* by Alvah Peterson, 5th edition (1947), published by Edwards Brothers Inc., Ann Arbor, Michigan.

Insects are usually killed in a cyanide killing bottle. This may be prepared by crushing an amount of potassium cyanide sufficient to cover the bottom of the bottle to a depth of half an inch. Another half inch of dry plaster of paris is poured in and tightly packed down. Finally, half an inch of a thick cream of this material is added and the bottle left uncorked overnight to dry. The mixture is covered with several discs of blotting paper, and the upper discs should remain quite dry. A well-fitting cork is essential.

Chloroform and benzine are sometimes used for killing and are applied on cotton wool or felt in the bottom of the bottle, excess being avoided. These agents require frequent recharging.

The size of the killing bottle depends on the size of the insects, and for ordinary purposes a strong glass tube about one inch in diameter and six inches deep is satisfactory.

After killing, the insects are emptied into small tubes or pill-boxes containing crushed tissue-paper, and conveyed to the laboratory for mounting and preservation.

Insects are preserved by impaling them on a pin whilst the tissues are still soft, and then storing them in specially constructed store boxes with a cork lining. Insects that have become dry must be relaxed before pinning by submitting them to a moist atmosphere in an airtight box. Special entomological pins are required. These are japanned, silvered, nickelled, or made of stainless steel, and are available in several sizes, varying in length and thickness. Large tabanids may require a No. 2 pin, small tabanids, house-flies, etc., a No. 5 or No. 7 pin. With moderate-sized to large specimens the pin is passed through the middle of the mesothorax, a sufficient length of pin being left above the insect for handling with forceps without any danger of damaging the specimen.

Small insects such as mosquitoes and sandflies are double-mounted. A No. 20 pin is passed through one end of a short piece of polyporous pith or photographic film, measuring half an inch by a quarter of an inch, for about two-thirds of its length.The insect is impaled either between the coxae of the middle legs or through the side of the thorax. If a number of individuals of a species are available, both types of mounts are desirable. The head of the pin may then be snipped off. A No. 5 pin is passed through the other end of the pith or celluloid with the head of the pin on the same side as the insect. The larger pin is inserted into the cork layer of the store box. Sandflies may also be preserved in 70 per cent alcohol. Indeed, many entomologists prefer this method of preservation.

Some entomologists prefer to gum tiny insects to the point of a small triangular piece of white card, the insect being placed on its side. The formula for such a gum is:

Gum arabic	60 parts
Sugar	30 parts
Carbolic acid	2 parts
Alcohol (95 per cent) ..	8 parts
Water	45 parts

Pinned insects should be handled only by special entomological forceps, which are designed to give a good grasp of the pins.

Store boxes require frequent inspection, for the dried specimens are readily attacked by small beetle larvae and psochids, and in damp climates are susceptible to moulds. Equal parts of naphthalene and carbolic acid heated together, crystallized quickly in water, placed in small cloth bags or a pill box, and pinned in the store box, is an effective preventive against destructive insects and moulds. Carbon bisulphide is a good fumigant.

Examination is made with a good hand-lens or under a binocular dissecting microscope. The pin passing through the specimen is stuck into a small ball of plasticine, enabling the specimen to be viewed from any angle. Sometimes it is an advantage to make slide mounts of various structures, or of the whole insect if it is small. The wings are removed and the insect prepared for mounting in the manner detailed below for lice. After being passed through clove oil the wings are mounted in balsam with the insect.

Labels with the necessary data are neatly printed on small white cards and impaled on the pin beneath the insect, or, in slide specimens, gummed on one end of the slide.

The immature stages, such as larvae and pupae, may be killed in hot 70 per cent alcohol (80° C.) and stored in the same fluid. If the specimens are to be examined histologically, they should be fixed before preservation.

The required data are written on small pieces of good quality paper in pencil or black waterproof ink and placed in the bottle with the specimen.

WINGLESS INSECTS

After carefully examining the hosts, fleas and lice are collected with a small brush dipped in 70 per cent alcohol. Sometimes it may be necessary to use a pair of fine-pointed forceps, but great care is required, otherwise the specimen may be damaged. Good results on dogs and cats are obtained by dusting lightly with pyrethrum, derris, or DDT and then using a fine comb. These insects may be stored in 70 per cent alcohol.

Identification is made on specimens mounted on slides. The insect is heated in 10 per cent potassium hydroxide in a water bath for ten to twenty minutes, according to size and degree of chitinization. After several washings in clean water, the abdomen is pricked and the contents gently pressed out with the head of a pin. The specimen is then passed through 70 per cent, 90 per cent, and, finally, absolute alcohol, spending twenty to thirty minutes in each. Some workers prefer glacial acetic acid to alcohol. It is cleared in clove oil. After removing the specimen from the clove oil, the excess oil is absorbed with blotting paper and the specimen is placed on a blob of fairly thick Canada balsam on a clean side. The antennae and legs are then set in position. A cover glass is applied and allowed to settle without any pressure. Gentle heat is then applied to facilitate settling and to remove any air bubles, and some thin Canada balsam is run in if necessary. Small pieces of cover slip may be used to prevent undue pressure on the specimen and any subsequent distortion.

In the case of fleas, Bedford recommends soaking them in cold caustic soda (10 per cent) for nineteen hours and, after thorough washing in clean water, passing them through 70 per cent alcohol for fifteen minutes, and warm carbolic acid for twenty minutes (carbolic acid 100 grammes, water 10 millilitres). The fleas are then mounted in balsam.

A stain is sometimes used, especially for lice, when acid fuchsine will be found satisfactory.

Temporary mounts of lice, fleas, and similar insects may be made by placing them in lactophenol (carbolic acid 20 per cent, lactic acid 20 per cent, glycerine 40 per cent, and water 20 per cent), after maceration in caustic potash and washing in water.

Each slide should bear a label giving all relevant data.

MITES

A small brush or a mounted needle dipped in 70 per cent alcohol is a convenient method of collecting unattached species of mites, such as scrub itch-mites, red mites, etc. Attached scrub itch-mites are collected either as scrapings, which may damage many specimens, or by snipping out the piece of skin on which they are feeding. The mites will eventually detach and may be picked up on a wet needle. The larger mange-mites may be collected from the edges of lesions on a wet needle. The small species, such as *Sarcoptes* and *Notoedres*, are taken in scrapings and isolated in the laboratory. All mites are satisfactorily preserved in 90 per cent alcohol.

Unengorged specimens may be mounted from 90 per cent alcohol into Womersley's gum chloral medium, in which they clear fairly rapidly. After allowing several days for the medium to harden, the mount is sealed with a ringing preparation such as fairly thick balsam.

Womersley's medium is prepared by mixing finely ground gum arabic (40 grammes) into a paste with 50 millilitres of 26 per cent alcohol. This is heated in a water bath until solution is complete, and then filtered through several layers of fine bolting silk. Fifty grammes of phenol and 50 grammes of chloral hydrate are rubbed down until in solution and 10 grammes of glucose syrup and 20 grammes of glacial lactic acid are added. The mixture is then heated in a water bath and filtered through a Buchner funnel.

Polyvinyl alcohol is another good mountant into which the mites can be placed alive or direct from the preserving fluid. Type A Grade P.H. 349 is used and the powder is covered with water and left for twenty-four hours, when the water will have been absorbed. It is covered with water again and heated in a water bath until its consistency resembles that of condensed milk. To 54 parts of this mixture, 22 parts of lactic acid and 22 parts of phenol are added and well mixed. Sufficient picric acid may be included to faintly colour the mounted specimen. This mountant clears and sets more slowly than Womersley's gum chloral.

Engorged specimens are heated in caustic potash (10 per cent), and any blood removed by pricking and gentle pressure. After washing well in clean water they can then be mounted in gum chloral or polyvinyl alcohol.

Lactophenol makes a good temporary mount.

TICKS

Ticks may be collected from their hosts by smearing them with a thin oil, waiting ten to fifteen minutes, and detaching them with a slow, gentle pull, provided they have not fallen off in the meantime. Or they may be collected from the pastures by dragging a piece of white cotton flannel about one yard square over the vegetation. Argasid ticks are sought for in their hiding places. Ticks may be temporarily stored in 70 per cent alcohol, but, in order to preserve their colours, are best placed in chloroform-saturated 10 per cent formalin. The storage tubes are tightly corked and sealed with paraffin and are not opened for three months. Excess chloroform must be avoided.

Only unengorged larvae and nymphs are mounted and, for these, Womersley's gum chloral or polyvinyal alcohol is suitable.

Adults, engorged nymphs, and larvae are examined under the binocular dissecting microscope, though on occasions the higher magnification of the compound microscope may be required. The specimen must be quite dry and clean. A soft brush is useful for cleaning and it may be necessary to dissect away adhering tissues from the mouth-parts. A small piece of plasticine on a slide makes a good bed in which the specimen can be fixed for examination from any angle.

Reflected illumination from a built-in or a bench lamp is essential for examination.

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